U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

FIELD HANDBOOK FOR MINERAL EXAMINERS

United States Department of the Interior
Bureau of Land Management

Form 1221-2
(June 1969)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

MANUAL TRANSMITTAL SHEET

Release	3-253
Date	5/10/89

Subject

H-3890-1 - HANDBOOK FOR MINERALS EXAMINERS

1. Explanation of Material Transmitted: This release transmits the revised appendices for the existing Handbook. The revised text was transmitted earlier. The appendices are being issued in the same format as the text, in a field pocket size. An 8-1/2 x 11 size will not be issued.

2. Reports Required: None.

3. Material Superseded: The material superseded by this release is listed under "REMOVE' below. No other directives are superseded.

4. Filing Instructions: File in the "red binder" or "blue binder" Manual sets with Manual Section 3890. Use the existing special binders previously provided to house the Handbook.

REMOVE:	INSERT:
TC-3 (Rel. 3-104)	TC-3
Appendix I (Rel. 3-104)	Appendix I
Appendix II (Rel. 3-104)	Appendix II
Appendix III (Rel. 3-104)	Appendix III
Appendix IV (Rel. 3-104)	Appendix IV
Appendix V (Rel. 3-104)	Appendix V
(Total: 39 Sheets)	(Total: 37 Sheets)

Hillary A. Oden

Assistant Director
Energy and Mineral Resources

Bureau of Land Management Handbook 3890-1

Procedures and Criteria for Conducting Mineral Examinations of Mining Claims on Federal Land

and

Appearing as an Expert Witness in an Administrative Hearing Before the Department of the Interior

H-3890-1 - HANDBOOK FOR MINERAL EXAMINERS

HANDBOOK FOR MINERAL EXAMINERS

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(Revised January 1989)

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I. Mapping and Surveying

ACKNOWLEDGMENTS

The use of the following material is hereby gratefully acknowledged:

Appendix

I - D. Courtesy of the U. S. Geological Survey
I - E. Courtesy of the U. S. Bureau of Mines
I - G. Courtesy of the U. S. Geological Survey
I - H. Courtesy of the U. S. Bureau of Mines
I - K. From Palmer, H.S. (1918): New Graphic Method for Determining the Depth and Thickness of Strata and the Projection of Dip; U. S. Geological Survey Professional Paper 120, U.S. Dept. of the Interior, 1918, pp 123, 128 plates XIV - XVI

Appendix	II- A.	Reprinted Courtesy of the Geological Society of America
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Appendix	III- E.	Courtesy of the U.S. Bureau of Mines
	III- F.	Courtesy of the U.S. Bureau of Mines

H-3890-1 - HANDBOOK FOR MINERAL EXAMINERS

Rectangular Survey System

Form 9600–5
(May 1978)
(formerly 9180–3)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

LAND DESCRIPTION DIAGRAM

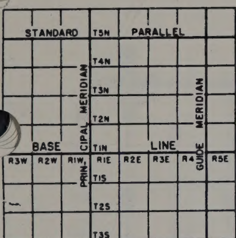
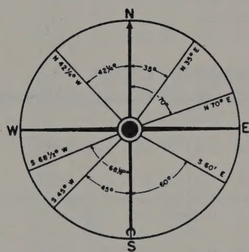
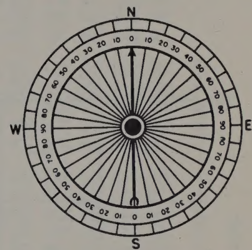


Diagram showing division of tract into Townships



60 seconds equal one minute
60 minutes equal one degree



90 degrees in a right angle
360 degrees in a circle

Sectional map of Township showing adjoining Sections

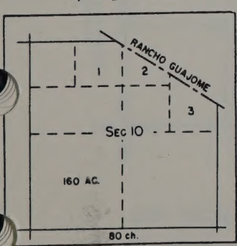
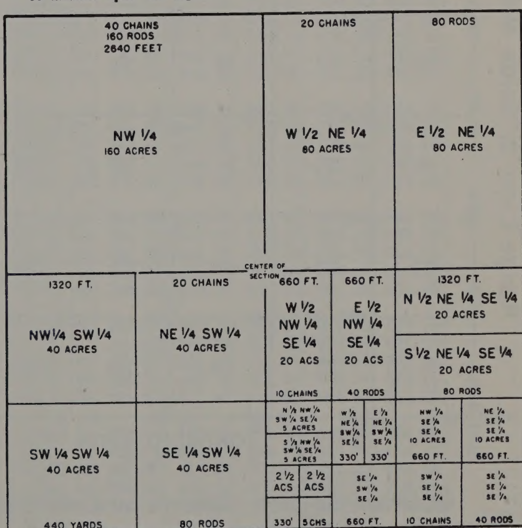
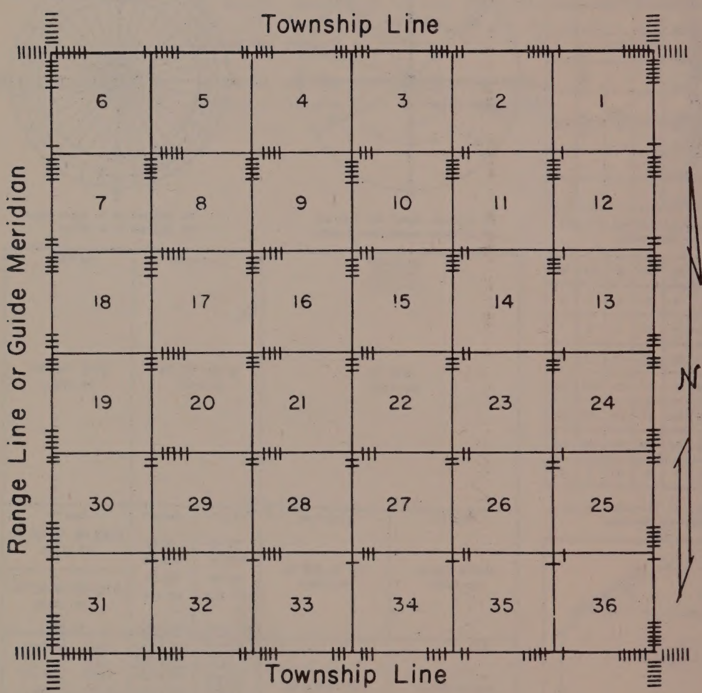


Diagram illustrating division of Fractional Section into Government Lots



Rectangular Survey System

MARKINGS FOR STONE SECTION CORNERS



Quarter-Section Corners are marked with the fraction "$\frac{1}{4}$", those on meridional lines on their west, and those on latitudinal lines on their north faces.

Surveying Tables of Chains and Links

Links	0 chs.	1 ch.	2 chs.	3 chs.	4 chs.	Links	0 chs.	1 ch.	2 chs.	3 chs.	4 chs.
	Feet	Feet	Feet	Feet	Feet		Feet	Feet	Feet	Feet	Feet
0	0.00	66.00	132.00	198.00	264.00	50	33.00	99.00	165.00	231.00	297.00
1	0.66	66.66	132.66	198.66	264.66	51	33.66	99.66	165.66	231.66	297.66
2	1.32	67.32	133.32	199.32	265.32	52	34.32	100.32	166.32	232.32	298.32
3	1.98	67.98	133.98	199.98	265.98	53	34.98	100.98	166.98	232.98	298.98
4	2.64	68.64	134.64	200.64	266.64	54	35.64	101.65	167.64	233.64	299.64
5	3.30	69.30	135.30	201.30	267.30	55	36.30	102.30	168.30	234.30	300.30
6	3.96	69.96	135.96	201.96	267.96	56	36.96	102.96	168.96	234.96	300.96
7	4.62	70.62	136.62	202.62	268.62	57	37.62	103.62	169.62	235.62	301.62
8	5.28	71.28	137.28	203.28	269.28	58	38.28	104.28	170.28	236.28	302.28
9	5.94	71.94	137.94	203.94	269.94	59	38.94	104.94	170.94	236.94	302.94
10	6.60	72.60	138.60	204.60	270.60	60	39.60	105.60	171.60	237.60	303.60
11	7.26	73.26	139.26	205.26	271.26	61	40.26	106.26	172.26	238.26	304.26
12	7.92	73.92	139.92	205.92	271.92	62	40.92	106.92	172.92	238.92	304.92
13	8.58	74.58	140.58	206.58	272.58	63	41.58	107.58	173.58	239.58	305.58
14	9.24	75.24	141.24	207.24	273.24	64	42.24	108.24	174.24	240.24	306.24
15	9.90	75.90	141.90	207.90	273.90	65	42.90	108.90	174.90	240.90	306.90
16	10.56	76.56	142.56	208.56	274.56	66	43.56	109.56	175.56	241.56	307.56
17	11.22	77.22	143.22	209.22	275.22	67	44.22	110.22	176.22	242.22	308.22
18	11.88	77.88	143.88	209.88	275.88	68	44.88	110.88	176.88	242.88	308.88
19	12.54	78.54	144.54	210.54	276.54	69	45.54	111.54	177.54	243.54	309.54
20	13.20	79.20	145.20	211.20	277.20	70	46.20	112.20	178.20	244.20	310.20
21	13.86	79.86	145.86	211.86	277.86	71	46.86	112.86	178.86	244.86	310.86
22	14.52	80.52	146.52	212.52	278.52	72	47.52	113.52	179.52	245.52	311.52
23	15.18	81.18	147.18	213.18	279.18	73	48.18	114.18	180.18	246.18	312.18
24	15.84	81.84	147.84	213.84	279.84	74	48.84	114.84	180.84	246.84	312.84
25	16.50	82.50	148.50	214.50	280.50	75	49.50	115.50	181.50	247.50	313.50
26	17.16	83.16	149.16	215.16	281.16	76	50.16	116.16	182.16	248.16	314.16
27	17.82	83.82	149.82	215.82	281.82	77	50.82	116.82	182.82	248.82	314.82
28	18.48	84.48	150.48	216.48	282.48	78	51.48	117.48	183.48	249.48	315.48
29	19.14	85.14	151.14	217.14	283.14	79	52.14	118.14	184.14	250.14	316.14
30	19.80	85.80	151.80	217.80	283.80	80	52.80	118.80	184.80	250.80	316.80
31	20.46	86.46	152.46	218.46	284.46	81	53.46	119.46	185.46	251.46	317.46
32	21.12	87.12	153.12	219.12	285.12	82	54.12	120.12	186.12	252.12	318.12
33	21.78	87.78	153.78	219.78	285.78	83	54.78	120.78	186.78	252.78	318.78
34	22.44	88.44	154.44	220.44	286.44	84	55.44	121.44	187.44	253.44	319.44
35	23.10	89.10	155.10	221.10	287.10	85	56.10	122.10	188.10	254.10	320.10
36	23.76	89.76	155.76	221.76	287.76	86	56.76	122.76	188.76	254.76	320.76
37	24.42	90.42	156.42	222.42	288.42	87	57.42	123.42	189.42	255.42	321.42
38	25.08	91.08	157.08	223.08	289.08	88	58.08	124.08	190.08	256.08	322.08
39	25.74	91.74	157.74	223.74	289.74	89	58.74	124.74	190.74	256.74	322.74
40	26.40	92.40	158.40	224.40	290.40	90	59.40	125.40	191.40	257.40	323.40
41	27.06	93.06	159.06	225.06	291.06	91	60.06	126.06	192.06	258.06	324.06
42	27.72	93.72	159.72	225.72	291.72	92	60.72	126.72	192.72	258.72	324.72
43	28.38	94.38	160.38	226.38	292.38	93	61.38	127.38	193.38	259.38	325.38
44	29.04	95.04	161.04	227.04	293.04	94	62.04	128.04	194.04	260.04	326.04
45	29.70	95.70	161.70	227.70	293.70	95	62.70	128.70	194.70	260.70	326.70
46	30.36	96.36	162.36	228.36	294.36	96	63.36	129.36	195.36	261.36	327.36
47	31.02	97.02	163.02	229.02	295.02	97	64.02	130.02	196.02	262.02	328.02
48	31.68	97.68	163.68	229.68	295.68	98	64.68	130.68	196.68	262.68	328.68
49	32.34	98.34	164.34	230.34	296.34	99	65.34	131.34	197.34	263.34	329.34
50	33.00	99.00	165.00	231.00	297.00	100	66.00	132.00	198.00	264.00	330.00

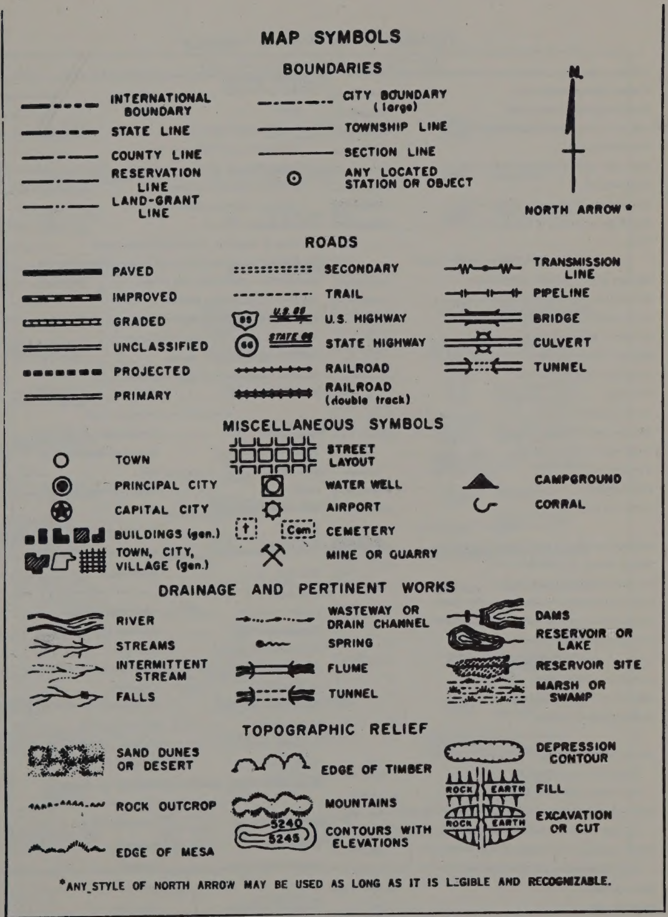
Links	5 chs.	6 chs.	7 chs.	8 chs.	9 chs.	Links	5 chs.	6 chs.	7 chs.	8 chs.	9 chs.
	Feet	Feet	Feet	Feet	Feet		Feet	Feet	Feet	Feet	Feet
0	330.00	396.00	462.00	528.00	594.00	50	363.00	429.00	495.00	561.00	627.00
1	330.66	396.66	462.66	528.66	594.66	51	363.66	429.66	495.66	561.66	627.66
2	331.32	397.32	463.32	529.32	595.32	52	364.32	430.32	496.32	562.32	628.32
3	331.98	397.98	463.98	529.98	595.98	53	364.98	430.98	496.98	562.98	628.98
4	332.64	398.64	464.64	530.64	596.64	54	365.64	431.64	497.64	563.64	629.64
5	333.30	399.30	465.30	531.30	597.30	55	366.30	432.30	498.30	564.30	630.30
6	333.96	399.96	465.96	531.96	597.96	56	366.96	432.96	498.96	564.96	630.96
7	334.62	400.62	466.62	532.62	598.62	57	367.62	433.62	499.62	565.62	631.62
8	335.28	401.28	467.28	533.28	599.28	58	368.28	434.28	500.28	566.28	632.28
9	335.94	401.94	467.94	533.94	599.94	59	368.94	434.94	500.94	566.94	632.94
10	336.60	402.60	468.60	534.60	600.60	60	369.60	435.60	501.60	567.60	633.60
11	337.26	403.26	469.26	535.26	601.26	61	370.26	436.26	502.26	568.26	634.26
12	337.92	403.92	469.92	535.92	601.92	62	370.92	436.92	502.92	568.92	634.92
13	338.58	404.58	470.58	536.58	602.58	63	371.58	437.58	503.58	569.58	635.58
14	339.24	405.24	471.24	537.24	603.24	64	372.24	438.24	504.24	570.24	636.24
15	339.90	405.90	471.90	537.90	603.90	65	372.90	438.90	504.90	570.90	636.90
16	340.56	406.56	472.56	538.56	604.56	66	373.56	439.56	505.56	571.56	637.56
17	341.22	407.22	473.22	539.22	605.22	67	374.22	440.22	506.22	572.22	638.22
18	341.88	407.88	473.88	539.88	605.88	68	374.88	440.88	506.88	572.88	638.88
19	342.54	408.54	474.54	540.54	606.54	69	375.54	441.54	507.54	573.54	639.54
20	343.20	409.20	475.20	541.20	607.20	70	376.20	442.20	508.20	574.20	640.20
21	343.86	409.86	475.86	541.86	607.86	71	376.86	442.86	508.86	574.86	640.86
22	344.52	410.52	476.52	542.52	608.52	72	377.52	443.52	509.52	575.52	641.52
23	345.18	411.18	477.18	543.18	609.18	73	378.18	444.18	510.18	576.18	642.18
24	345.84	411.84	477.84	543.84	609.84	74	378.84	444.84	510.84	576.84	642.84
25	346.50	412.50	478.50	544.50	610.50	75	379.50	445.50	511.50	577.50	643.50
26	347.16	413.16	479.16	545.16	611.16	76	380.16	446.16	512.16	578.16	644.16
27	347.82	413.82	479.82	545.82	611.82	77	380.82	446.82	512.82	578.82	644.82
28	348.48	414.48	480.48	546.48	612.48	78	381.48	447.48	513.48	579.48	645.48
29	349.14	415.14	481.14	547.14	613.14	79	382.14	448.14	514.14	580.14	646.14
30	349.80	415.80	481.80	547.80	613.80	80	382.80	448.80	514.80	580.80	646.80
31	350.46	416.46	482.46	548.46	614.46	81	383.46	449.46	515.46	581.46	647.46
32	351.12	417.12	483.12	549.12	615.12	82	384.12	450.12	516.12	582.12	648.12
33	351.78	417.78	483.78	549.78	615.78	83	384.78	450.78	516.78	582.78	648.78
34	352.44	418.44	484.44	550.44	616.44	84	385.44	451.44	517.44	583.44	649.44
35	353.10	419.10	485.10	551.10	617.10	85	386.10	452.10	518.10	584.10	650.10
36	353.76	419.76	485.76	551.76	617.76	86	386.76	452.76	518.76	584.76	650.76
37	354.42	420.42	486.42	552.42	618.42	87	387.42	453.42	519.42	585.42	651.42
38	355.08	421.08	487.08	553.08	619.08	88	388.08	454.08	520.08	586.08	652.08
39	355.74	421.74	487.74	553.74	619.74	89	388.74	454.74	520.74	586.74	652.74
40	356.40	422.40	488.40	554.40	620.40	90	389.40	455.40	521.40	587.40	653.40
41	357.06	423.06	489.06	555.06	621.06	91	390.06	456.06	522.06	588.06	654.06
42	357.72	423.72	489.72	555.72	621.72	92	390.72	456.72	522.72	588.72	654.72
43	358.38	424.38	490.38	556.38	622.38	93	391.38	457.38	523 38	589.38	655.38
44	359.04	425.04	491.04	557.04	623.04	94	392.04	458.04	524.04	590.04	656.04
45	359.70	425.70	491.70	557.70	623.70	95	392.70	458.70	524.70	590.70	656.70
46	360.36	426.36	492.36	558.36	624.36	96	393.36	459.36	525.36	591.36	657.36
47	361.02	427.02	493.02	559.02	625.02	97	394.02	460.02	526.02	592.02	658.02
48	361.68	427.68	493.68	559.68	625.68	98	394.68	460.68	526.68	592.68	658.68
49	362.34	428.34	494.34	560.34	626.34	99	395.34	461.34	527.34	593.34	659.34
50	363.00	429.00	495.00	561.00	627.00	100	396.00	462.00	528.00	594.00	660.00

For conversion of even or whole chains, up to 100 chains, use columns zero chains and links, and place decimal two points to the right.

Map Scales in English and Metric Units

FRACTIONAL SCALE	FEET PER INCH	IN PER 100 FT	INCHES PER MILE	MILES PER IN	METERS PER IN	ACRES PER SQ INCH	SQ IN PER ACRE	SQ MI PER SQ INCH
1:500	41.667	24.00	126.72	0.008	12.700	0.0399	25.091	0.00006
1:600	50.00	20.00	105.60	0.009	15.240	0.0574	17.424	0.00009
1:1000	83.333	12.00	63.36	0.016	25.4000	0.1594	6.273	0.00025
1:1200	100.00	10.00	52.80	0.019	30.480	0.2296	4.356	0.00036
1:1500	125.00	8.00	42.24	0.024	38.100	0.3587	2.788	0.00056
1:2000	166.667	6.00	31.68	0.032	50.800	0.6377	1.568	0.00100
1:2400	200.00	5.00	26.40	0.038	60.960	0.9183	1.089	0.0014
1:2500	208.333	4.80	25.344	0.039	63.500	0.9964	1.004	0.0016
1:3000	250.00	4.00	21.12	0.047	76.200	1.4348	0.697	0.0022
1:3600	300.00	3.333	17.60	0.057	91.440	2.0661	0.484	0.0032
1:4000	633.333	3.00	15.84	0.063	101.600	2.5508	0.392	0.0040
1:4800	400.00	2.50	13.20	0.076	121.920	3.6731	0.272	0.0057
1:5000	416.667	2.40	12.672	0.079	127.000	3.9856	0.251	0.0062
1:6000	500.00	2.00	10.56	0.005	142.400	5.7392	0.174	0.0090
1:7000	583.333	1.714	9.051	0.110	177.800	7.8117	0.128	0.0122
1:7200	600.00	1.667	8.80	0.114	182.880	8.2645	0.121	0.0129
1:7920	660.00	1.515	8.00	0.125	201.168	10.00	0.00	0.0156
1:8000	666.667	1.500	7.92	0.126	203.200	10.203	0.098	0.0159
1:8400	700.00	1.429	7.543	0.133	213.360	11.249	0.089	0.0176
1:9000	750.00	1.333	7.041	0.142	228.600	12.913	0.077	0.0202
1:9600	800.00	1.250	6.60	0.152	243.840	14.692	0.068	0.0230
1:10000	833.333	1.200	6.336	0.158	254.000	15.942	0.063	0.0249
1:10800	900.00	1.111	5.867	0.170	274.321	18.595	0.054	0.0291
1:12000	1000.00	1.0	5.280	0.189	304.801	22.957	0.044	0.0359
1:13200	1100.00	0.909	4.800	0.208	335.281	27.778	0.036	0.0434
1:14400	1200.00	0.833	4.400	0.227	365.761	33.058	0.030	0.0517
1:15000	1250.00	0.80	4.224	0.237	381.001	35.870	0.028	0.0560
1:15600	1300.00	0.769	4.062	0.246	396.241	38.797	0.026	0.0606
1:15840	1320.00	0.758	4.00	0.250	402.337	40.000	0.025	0.0625
1:16000	1333.333	0.750	3.96	0.253	406.400	40.812	0.024	0.0638
1:16800	1400.00	0.714	3.771	0.265	426.721	44.995	0.022	0.0703
1:18000	1500.00	0.667	3.52	0.284	457.201	51.653	0.019	0.0807
1:19200	1600.00	0.625	3.30	0.303	487.681	58.770	0.017	0.0918
1:20000	1666.667	0.60	3.168	0.316	508.002	63.769	0.016	0.0996
1:20400	1700.00	0.588	3.106	0.322	518.161	66.345	0.015	0.1037
1:21120	1760.00	0.568	3.00	0.333	536.449	71.111	0.014	0.1111
1:21600	1800.00	0.556	2.933	0.341	548.641	74.380	0.013	0.1162
1:22800	1900.00	0.526	2.779	0.360	579.121	82.874	0.012	0.1295
1:24000	2000.00	0.50	2.640	0.379	609.601	91.827	0.011	0.1435
1:25000	2083.333	0.480	2.534	0.395	635.001	99.639	0.010	0.1557
1:31680	2640.00	0.379	2.000	0.500	804.674	160.000	0.006	0.2500
1:48000	4000.00	0.250	1.320	0.758	1219.202	367.309	0.003	0.5739
1:62500	5208.333	0.192	1.014	0.986	1587.503	622.744	0.0016	1.0000
1:63360	5280.00	0.189	1.000	1.000	1609.347	640.00	1.0016	1.0000
1:96000	8000.00	0.125	0.660	1.515	2438.405	1469.24	0.0007	2.2957
1:125000	10416.667	0.096	0.507	1.973	3175.006	2490.98	0.0004	3.8922
1:126720	10560.00	0.095	0.500	2.00	3218.694	2560.00	0.0004	4.00
1:250000	29833.333	0.048	0.253	3.946	6350.012	9963.907	0.0001	15.5686
1:253440	21120.00	0.047	0.250	4.00	6437.389	10244.202	0.0001	16.00
1:500000	41666.667	0.024	0.127	7.891	12700.025	39855.627	0.425	62.2744
1:1000000	83333.333	0.012	0.063	15.783	25400.050	159422.507	0.562	249.0977
Formulas	$\frac{\text{Scale}}{12}$	$\frac{12000}{\text{Scale}}$	$\frac{63360}{\text{Scale}}$	$\frac{\text{Scale}}{63360}$	(Ft/in) X 0.3048	$\frac{(\text{Scale})^2}{6272640}$	$\frac{6272640}{(\text{Scale})^2}$	$\frac{(\text{Ft/in})^2}{27878400}$

Standard Topographic Map Symbols



Standard Topographic Map Symbols

TOPOGRAPHIC MAP SYMBOLS

VARIATIONS WILL BE FOUND ON OLDER MAPS

Primary highway, hard surface
Secondary highway, hard surface
Light-duty road, hard or improved surface
Unimproved road
Road under construction, alinement known
Proposed road
Dual highway, dividing strip 25 feet or less
Dual highway, dividing strip exceeding 25 feet
Trail

Railroad: single track and multiple track
Railroads in juxtaposition
Narrow gage: single track and multiple track
Railroad in street and carline
Bridge: road and railroad
Drawbridge: road and railroad
Footbridge
Tunnel: road and railroad
Overpass and underpass
Small masonry or concrete dam
Dam with lock
Dam with road
Canal with lock

Buildings (dwelling, place of employment, etc.)
School, church, and cemetery ... Cem
Buildings (barn, warehouse, etc.)
Power transmission line with located metal tower
Telephone line, pipeline, etc. (labeled as to type)
Wells other than water (labeled as to type) ... Oil ... Gas
Tanks: oil, water, etc. (labeled only if water) ... Water
Located or landmark object; windmill
Open pit, mine, or quarry; prospect
Shaft and tunnel entrance

Horizontal and vertical control station:
Tablet, spirit level elevation ... BM Δ 5653
Other recoverable mark, spirit level elevation ... Δ 5455
Horizontal control station: tablet, vertical angle elevation ... VABM Δ 9519
Any recoverable mark, vertical angle or checked elevation ... Δ 3775
Vertical control station: tablet, spirit level elevation ... BM × 957
Other recoverable mark, spirit level elevation ... × 954
Spot elevation ... × 7369 × 7369
Water elevation ... 670 670

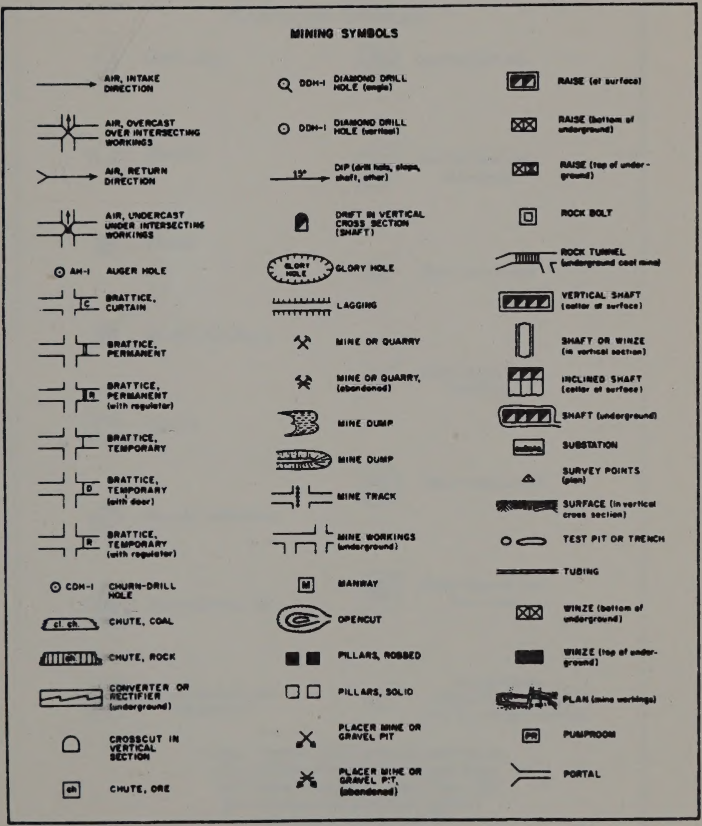
Boundaries: National
State
County, parish, municipio
Civil township, precinct, town, barrio
Incorporated city, village, town, hamlet
Reservation, National or State
Small park, cemetery, airport, etc.
Land grant
Township or range line, United States land survey
Township or range line, approximate location
Section line, United States land survey
Section line, approximate location
Township line, not United States land survey
Section line, not United States land survey
Found corner: section and closing
Boundary monument: land grant and other
Fence or field line

Index contour
Intermediate contour
Supplementary contour
Depression contours
Fill
Cut
Levee
Levee with road
Mine dump
Wash
Tailings
Tailings pond
Shifting sand or dunes
Intricate surface
Sand area
Gravel beach

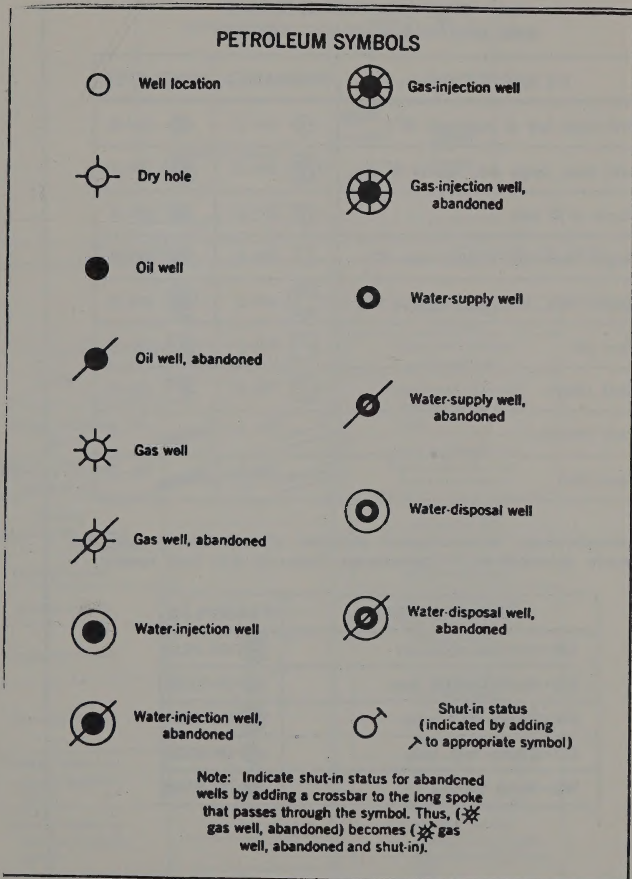
Perennial streams
Intermittent streams
Elevated aqueduct
Aqueduct tunnel
Water well and spring
Glacier
Small rapids
Small falls
Large rapids
Large falls
Intermittent lake
Dry lake bed
Foreshore flat
Rock or coral reef
Sounding, depth curve ... 10
Piling or dolphin
Exposed wreck
Sunken wreck
Rock, bare or awash; dangerous to navigation

Marsh (swamp)
Submerged marsh
Wooded marsh
Mangrove
Woods or brushwood
Orchard
Vineyard
Scrub
Land subject to controlled inundation
Urban area

Standard Mining Symbols



Standard Drill Hole and Well Symbols



Standard Drill Hole and Well Symbols

MAP SYMBOLS FOR GEOLOGIC AND MATERIALS INVESTIGATIONS

DESCRIPTION	PROPOSED	COMPLETED
Drill hole (up to and incl. 6")	DH-2	DH-2
Drill hole, large dia. (above 6")	DH-2	DH-2
Angle drill hole	DH-2	DH-2
Auger hole (up to and incl. 6")	AH-2	AH-2
Auger hole, large dia. (above 6")	AH-2	AH-2
Test pit	TP-2	TP-2
Test shaft	TS-2	TS-2
Test trench	TT-2	TT-2
Test drift	TD-2	TD-2

When advantageous, indicate special character of drill hole or sampling by these abbreviations in parentheses, following drill hole number.

DESIGNATIONS	EXAMPLES
DN = Denison samples	DH-2(DN)
DS = Drive-sample hole	DH-3(DS)
CX = Calyx-drill hole	DH-4(CX)
CD = Churn-drill hole	DH-5(CD)
WB = Wash boring	DH-6(WB)

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Standard Geologic Map Symbols

Outcrops

Bedrock outcrop	
Limit of outcrop	4=29% 7=63% 3=20%

Contacts

Contact	KJs
Contact, showing dip	50 45
Overturned contact, showing dip	65
Contact, approximately located	
Indefinite contact	
Inferred contact	
Gradational contact	
Concealed contact	(KJs)
Contact, located by ground magnetic survey	
Contact, located by airborne magnetic survey	

Attitude of Beds

Strike and dip of beds	45
Strike and direction of dip of beds	
Approximate strike and direction of dip of beds	
Strike and dip of beds *Top of beds known from sedimentary features*	30
Strike and dip of overturned beds	65
Strike and dip of overturned beds *Top of beds known*	65
Strike of vertical beds	
Strike of vertical beds *Dot indicates top of beds*	
Component of dip *Dot marks point of observation*	
Horizontal beds	⊕
Strike and dip of beds and plunge of slickensides	40 60
Crumpled, plicated, crenulated, or undulatory beds and average dip	55

Geologic Map Symbols

Faults

Fault *Bar and ball on downthrown side*	
Fault *Showing relative horizontal movement*	
Fault *Showing bearing and plunge of slickensides on fault plane. D, downthrown side*	D 60 Normal D 60 Reverse
Normal fault *Hachures on apparently downthrown side*	
Reverse fault *R, upthrown side*	R
Thrust fault *T, upper plate*	T 45
Thrust fault *Sawteeth on upper plate*	
Overturned thrust fault *Sawteeth in direction of dip; bar on side of tectonically higher plate*	
Fault (shear or mylonite) zone, showing dip	55
Fault breccia	
Fault, intruded by dike	
Fault, intruded by dike	
Subsurface fault	

Fault	OWL CREEK FAULT
Fault, showing dip	90 65
Fault, approximately located	
Inferred fault	
Probable fault	---?----?----?-
Doubtful fault	
Concealed fault	
Hypothetical fault	? ? ?
Fault, located by ground magnetic survey	
Fault, located by airborne magnetic survey	
Fault, or lineament from aerial photographs *Not checked or identified on ground*	
Lineament	
Fault *Showing bearing and plunge of grooves, striations, or slickensides*	60
Fault *Showing dip and amount of displacement in meters. U, upthrown side, D, downthrown side*	80 D U

Geologic Map Symbols

Foliation or Shistosity

Strike and dip of foliation	70
Strike and direction of dip of foliation	
Strike of vertical foliation *Relationship of foliation (or schistosity) to bedding not shown in outcrop*	
Horizontal foliation	
Strike and dip of foliation and parallel bedding	10
Strike of vertical foliation and parallel bedding	
Strike and dip of foliation and parallel overturned bedding	40
Horizontal foliation and bedding	

Cleavage

Strike and dip of cleavage	15		
Strike of vertical cleavage			
Horizontal cleavage			
Inclined			
Vertical			
Horizontal			

Joints

Strike and dip of joints	40
Strike and direction of dip of joints	
Strike of vertical joints	
Horizontal joints	
Strikes and dips of multiple joints	50 60 40

Linear Features

Bearing of plunge of lineation	15
Vertical lineation	
Horizontal lineation	
Strike and dip of foliation and plunge of lineation	75 30
Vertical foliation showing horizontal lineation	
Strike and dip of foliation showing horizontal lineation	40
Strike and dip of beds and plunge of lineation	25 60
Vertical foliation and vertical lineation	
Strike of vertical foliation showing plunge of lineation	70
Vertical beds showing horizontal lineation	
Horizontal beds, showing trend of horizontal lineation	
Vertical beds showing plunge of lineation	60
Approximate strike of folded beds showing plunge of fold axes	70
Attitude of foliation and overturned beds, strikes parallel but dips differ	30 50
Double lineation	40 45
Strike and dip of beds intersecting slip cleavage	30 45
Strike and dip of beds intersecting slip cleavage	75 70

Geologic Map Symbols

Folds

Anticline *Showing trace of crestal plane. Dashed where approximately located*	
Anticline *Showing trace of crestal plane and direction of plunge*	
Anticline *Showing trace of crestal plane and plunge*	20
Asymmetric anticline *Showing trace of crestal plane and plunge. Short arrow indicates steeper limb*	15
Asymmetric anticline *Showing dip of limbs and plunge*	20, 20, 50
Overturned anticline *Showing direction of dip of limbs and plunge*	10
Inferred anticline or Probable anticline	---------------
Doubtful anticline	---?----------?---
Concealed anticline	....
Dome	
Inverted anticline	
Antiform *Drawn on foliation, cleavage or bedding*	

Syncline *Showing trace of trough plane. Dashed where approximately located*	
Syncline *Showing trace of trough plane and direction of plunge*	
Syncline *Showing trace of trough plane and plunge*	15
Asymmetric syncline *Showing trace of trough plane and plunge. Short arrow indicates steeper limb*	10
Asymmetric syncline *Showing dip of limbs and plunge*	25, 50, 20
Overturned syncline *Showing direction of dip of limbs and direction of plunge*	
Inferred syncline or Probable syncline	---------------
Doubtful syncline	--?----------?--
Concealed syncline	....
Basin	
Inverted syncline *Arrows show direction of dip of limbs*	
Synform *Drawn on foliation, cleavage or bedding*	

Geologic Map Symbols

Folds

Monoclines

Monocline *Showing trace and direction of plunge. Dashed where approximately located*	
Anticlinal bend *Showing trace and direction of plunge. Dashed where approximately located*	A
Synclinal bend *Showing trace and direction of plunge. Dashed where approximately located*	S

Minor Fold Axes

Minor anticline *Showing plunge*	20
Minor syncline *Showing plunge*	50
Minor fold axis *Showing plunge*	FA 15
Minor fold axis, horizontal	FA
Minor folds *Showing plunge of axes*	75

Contours and Isopleths

Structure contours *Drawn on top (or base) of geologic horizon. Dashed where control is poor. Contour interval 20 feet. Arrow indicates direction of dip*	2000
Outcrop point *Used for structural control*	x
Magnetic contours *Showing total intensity magnetic field of the earth in gammas relative to arbitrary datum. Hachured to indicate closed areas of lower magnetic intensity, dashed where data are incomplete. Contour interval 20 gammas*	2000
Maximum or minimum intensity *Location measured within closed high or closed low*	x 7864
Flight Path *Showing location and spacing of data*	
Isoradioactivity contours (or isograds) *Interval 50 counts per second (airborne survey). Interval 50 microroentgens per hour (ground surveys)*	
Gravity contours (or Isogals) *Dashed where control is poor. Contour interval 1 milligal*	
Gravity station and number	. 635
Isopachs *Dashed where control is poor. Interval 3 meters*	
Mineral isograds *Metamorphic zones indicated by mineral names*	SILLIMANITE STAUROLITE

Geologic Map Symbols

Ores, Veins, Alteration

Vein, showing dip	50
Ore body	
Mineralized stringers or veinlets	
Altered wallrock *Showing intensity of alteration by concentration of dots*	
Dike	

Sedimentary Ores, Structures

Strike of roll *Showing geometric configuration in cross section*	
Direction of plunge of cross-stratification in sandstone *Showing direction of flow of depositing stream*	
Fossil Log	
Lineation trend	
Festoon trend	

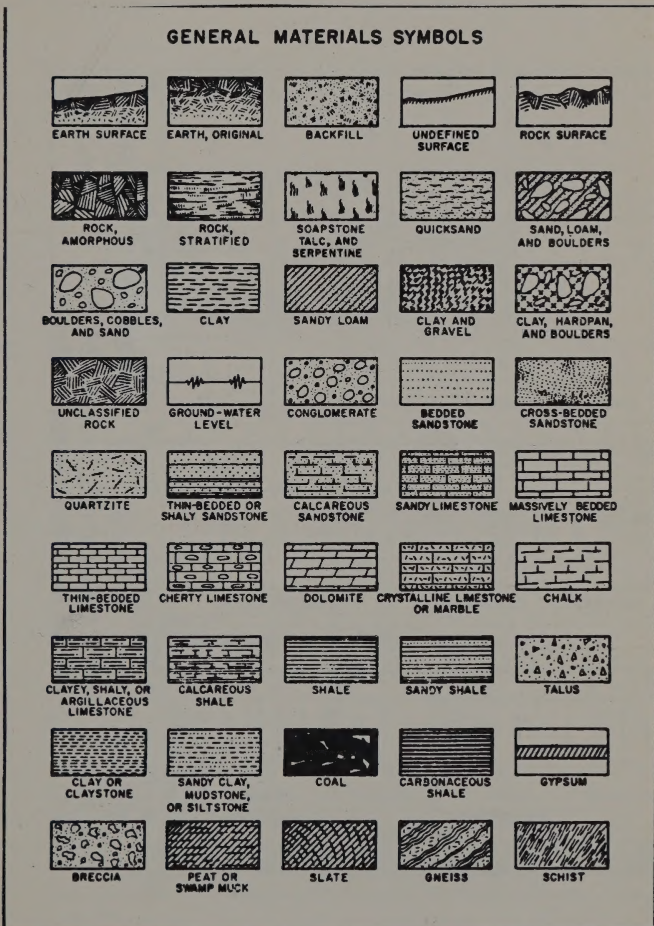
Surface Workings

Vertical shaft	
Inclined shaft	
Portal or adit	
Portal and opencut	
Trench	
Prospect pit or open cut	
Mine dump	

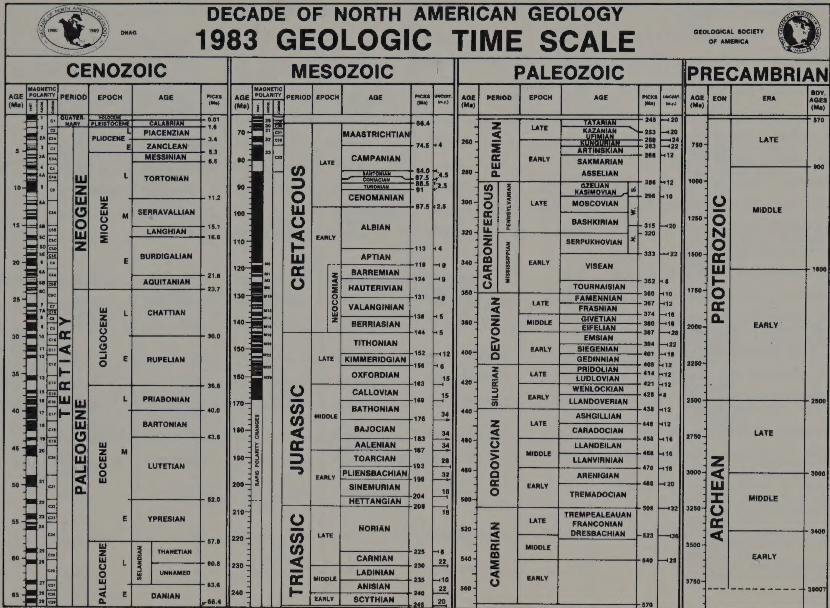
Large Scale Maps

Drill hole *Showing name and number*	PAHUTE 2
Drill hole *No geologic data available*	ND
Diamond-drill hole	DDH
Drill hole, low-grade ore	
Drill hole, high-grade ore	
Drill hole, inclined *Showing bearing and inclination; surface position and altitude; vertical projection of bedrock surface, bottom of hole, and thickness of overburden; and length of hole, in meters*	45° 3620 45

Standard Earth Material Symbols



Geologic Time Scale for North America



Name	Formula	Percent metal	Color	Lustre	Streak	Hardness	Specific gravity	Characteristics—occurrence
Actinolite	$Ca(MgFe)_3(SiO_3)_4$.	No metal source.	Green	Vitreous		5.0–6.0	3.0–3.2	Usually long crystals, columnar or fibrous.
Albite	$NaAlSi_3O_8$	Al_2O_3—19.5%	White to blue	Vitreous	White	6.0–6.6	2.6–2.7	Occurs sometimes in platy masses. Otherwise like anorthite. See anorthite.
Almandite	$Fe_3Al_2(SiO_4)_3$	No metal source.	Red to black		White	6.5–7.5	3.1–4.3	Variety of garnet. See garnet.
Altaite	PbTe	61.9% Pb	Tin white, yellow tinge.	Metallic	Grayish black	3.0	8.2	Associated with pyrite, galena, tetrahedrite.
Alunite	$K_2(Al_2OH)_6(SO_4)_4$.	K—9.4% Al—19.6%.	Pink-red	Vitreous pearly.	White	3.8	2.7	Associated with kaolin and pyrite.
Amosite	$(FeCaH_2Mn)OSiO_2$.	No metal source.	Gray to green				2.2–2.3	Long fibered asbestos.
Analcite	$NaAlSi_2O_6 \cdot 2H_2O$.	Al_2O_3—23.2%	White	Vitreous	White	5.0–5.5	2.2–2.3	Trapezohedral crystals in cavities in basic igneous rocks.
Andalusite	Al_2SiO_5	Al_2O_3—63.2%	White, red-green.	Vitreous		7.5	3.2	Nearly square prisms; occurs with gneiss, mica, schists.
Andradite	$Ca_3Fe_2(SiO_4)_3$	No metal source.	Green, red-black.	Adamantine	White	6.5–7.5	3.1–4.3	Variety of garnet. See garnet.
Anglesite	$PbSO_4$	Pb—68.3%	Yellow, green-gray.	Adamantine, vitreous.	White	2.8–3.0	6.1–6.4	Occurs in oxidation zones of lead veins.
Anorthite	$CaAl_2Si_2O_8$	Al_2O_3—36.7%	White, gray-red.	Vitreous	White	6.0–6.5	2.7–2.8	Tabular crystals in igneous rocks, with fine longitudinal lines on the better of two perfect cleavages at 90° to each other.
Anthophyllite	$(MgFe)SiO_3$	No metal source.	Gray, brown-green.	Vitreous	Uncolored, grayish.	5.0	3.0–3.2	Found in crystalline schists.
Apatite	$Ca_4(CaF)(PO_4)_3$.	P_2O_5—42.3%	Green-blue	Vitreous	White	4.5–5.0	3.2	Usually granular or in 6-sided prisms.
Aragonite	$CaCO_3$	CaO—56%	White	Vitreous	White	3.5–4.0	2.9	Effervesces like calcite. Powder becomes lilac or purple when boiled in 10X solution of cobalt nitrate.
Argentite	Ag_2S	Ag—87.1%	Black	Metallic	Shiny black	2.0–2.5	7.2–7.4	Cuts like lead; with silver, cobalt and nickel.
Argyrodite	$3Ag_2S \cdot GeS_2$	Ag—73.5%	Steel gray, red tinge.	Metallic	Grayish black	2.5	6.1	Occurs with sphalerite, siderite and marcasite.
Arsenopyrite	FeAsS	Fe—34.3% As—46.0%.	Steel gray	Metallic	Gray, black	5.5–6.0	5.9–6.3	Widely spread; yields sparks and garlic odor when struck slanting blows with steel.
Atacamite	$Cu_2(OH)_3Cl$	Cu—59.5%	Green	Adamantine, vitreous.	Apple green	3.0–3.5	3.8	Always of secondary origin with copper ores.
Azurite	$2CuCO_3 \cdot Cu(OH)_2$.	Cu—55.0%	Blue	Vitreous, dull	Blue	3.5–4.0	3.8–3.9	Oxidized mineral that effervesces vigorously in muriatic acid of any strength and temperature.
Barite	$BaSO_4$	BaO—65.7%	White, blue-red.	Vitreous	White	2.5–3.5	4.3–4.6	Found commonly as gangue of lead-zinc ores. Platy or granular masses or either diamond-shaped or rectangular crystals.
Bauxite	$Al_2O_3 \cdot 3H_2O$	Al—34.9%	White-red, brown-yellow.	Dull	Like color	1.0–3.0	2.6	Chief ore of aluminum; occurs massive. Completely soluble in salt of phosphorous bead.
Bentonite	$(CaMg)O \cdot SiO_2(AlFe)_2O_3$.	No metal source.	Blue	Dull	Light gray	1.0	2.1	The clay of montmorillonite. Swells greatly when placed in water.

Name	Formula	Percent metal	Color	Lustre	Streak	Hardness	Specific gravity	Characteristics—occurrence
Beryl	$Be_3Al_2(SiO_3)_6$	Be—5%. Al_2O_3—19%.	White, green-blue.	Vitreous	White	7.5-8.0	2.6-2.8	Often imbedded in quartz; with mica, feldspar. Usually in 6-sided prisms with flat terminations in pergmatite. Gem varieties.
Beryllonite	$NaBePO_4$	Be—7.1%	White-yellow	Vitreous, brilliant.	White	5.8	2.8	Found with beryl, feldspar, columbite.
Biotite	$(HK)_2(MgFe)_2Al_2(SiO_4)_3$.	No metal source.	Black-Brown	Pearly, vitreous.	White	2.5-3.0	2.7-3.1	Cleaves easily into very thin, flexible and elastic plates.
Bismite	Bi_2O_3	No metal source.	Straw yellow, white.	Pearly	Like color		4.4	Of secondary origin resulting from oxidation.
Bismuth	Bi	Bi—100%	Silver White	Metallic	Silver white	2.3	9.7	Native; with cobalt, nickel; brassy tarnish.
Bismuthinite	Bi_2S_3	Bi—81.2%	Lead gray	Metallic	Like color	2.0	6.4-6.5	Occurs in form of thin coating.
Bismutite	$(BiO)_2 \cdot CO_3 \cdot H_2O$.	No metal source.	Green-white	Vitreous, dull.	Greenish gray-white.	4.0	6.9-7.7	Incrusting fibrous, or earthy and pulverulent.
Borax	$Na_2B_4O_7 \cdot 10H_2O$.	B_2O_3—36.6%. Na_2O—16.2%.	White	Vitreous, dull.	White	2.0-2.5	1.7	Refer to introduction for characteristic taste.
Bornite	Cu_5FeS_4	Cu—63.3%	Reddish	Metallic	Blackish gray	3.0-3.5	4.9-5.4	Associated with chalcoite. Usually massive. Quickly tarnishes iridescent blue.
Bournonite	$3(PbCu_2)S.Sb_2S_3$.	Pb—24.7%. Cu—42.5%.	Steel gray, iron black.	Metallic	Like color	2.5-3.0	5.7-5.9	Occurs fine-grained massive; brittle.
Braunite	$3Mn_2O_3 \cdot MnSiO_3$.	Mn—78.3%	Steel gray, brownish black.	Submetallic	Like color	6.0-6.5	4.8	Occurs in porphyry; brittle.
Breithauptite	NiSb	Ni—32.5%. Sb—67.5%.	Copper red	Metallic	Reddish brown.	5.5	7.5	Occurs with other sulfides and silver minerals.
Brochantite	$CuSO_4 \cdot 3Cu(OH)_2$.	Cu—56.2%	Green	Vitreous	Green	3.5-4.0	3.9	Oxidized mineral. Dissolves quietly in nitric acid.
Brucite	$MgO \cdot H_2O$	MgO—69%	White to gray, blue, green.	Pearly, vitreous.	White	2.5	2.4	Associated with serpentine; secondary mineral.
Calamine	$H_2(Zn_2O) \cdot SiO_4$.	ZnO—67.5%	White, blue, green, brown.	Vitreous, dull.	White	4.5-5.0	3.4-3.5	Usually in crystal coatings; sometimes in cockscomb-like aggregates. Often with smithsonite.
Calaverite	$AuTe_2$	Au—43.6%	Bronze yellow, silver-yellow tinge.	Metallic	Yellowish gray	2.5	9.0	Similar to sylvanite, but never in crystals.
Calcite	$CaCO_3$	CaO—56%	Many colors	Vitreous	White	3.0	2.7	Massive and 6-sided pointed or prismatic crystals. Effervesces vigorously in muriatic acid of any strength or temperature.
Calomel	HgCl	Hg—85%. Cl—15%.	White, yellow.	Adamantine	Pale yellow, white.	1.0-2.0	6.5	Associated with cinnabar.
Carmallite	$KMgCl_3 \cdot 6H_2O$.	K—14.1%. Cl—38.3%.	White	Shining	White	2.5	1.6	Strongly phosphorescent; taste—bitter.
Carnotite	$K_2O \cdot 2U_2O_3 \cdot V_2O_5 \cdot 3H_2O$ variable.	Variable	Yellow	Vitreous, dull.	Yellow	1.5		Powder or earth in sandstone. Often concentrated around petrified wood.
Cassiterite	SnO_2	Sn—78.8%	Brown, black, red.	Adamantine	White, light brown.	6.0-7.0	6.8-7.1	Massive or squarish crystals.
Celestite	$SrSO_4$	Sr—47.7%	Light blue, white, red.	Vitreous	White	3.0-3.5	3.9-4.0	Same as barite.
Cerargyrite	AgCl	Ag—75.3%	Pearly gray	Waxy, greasy.	White to gray	1.0-1.5	5.6	Cuts like wax; exposure changes color to violet brown.
Cerussite	$PbCO_3$	Pb—77.5%	White, gray	Adamantine	White	3.0-3.5	6.5-6.6	Oxidized mineral. Effervesces vigorously in warm concentrated or boiling dilute muriatic acid.
Cervantite	$2Sb_2O_4 \cdot Sb_2O_3 \cdot Sb_2O_5$.	Sb—79.4%	Yellow reddish white.	Greasy, pearly.	White	4.0-5.0	4.1-5.3	Usually associated with stibnite.
Chalcanthite	$CuSO_4 \cdot 5H_2O$	CuO—31.8%	Blue	Vitreous	White	2.5	2.1-2.3	Oxidized mineral. Tastes metallic and nauseating.

Name	Formula	Percent metal	Color	Lustre	Streak	Hardness	Specific gravity	Characteristics—occurrence
Chalcedony	SiO_2	No metal source.	Pale blue, gray, white to black.	Waxy	White	7.0	2.6–2.7	Smoothly rounded fracture. Semi-precious gem varieties.
Chalcocite	Cu_2S	Cu—79.8%	Black-gray	Metallic	Like color	2.5–3.0	5.5–5.8	Highly polished surface where cut.
Chalcomenite	$CuSeO_3 \cdot 2H_2O$	Cu—28.1% Se—34.9%.	Blue	Vitreous	Bluish white	2.5–3.0	3.8	With various selenides of silver, copper, and lead.
Chalcopyrite	$CuFeS_2$	Cu—31.6%	Brassy yellow	Metallic	Greenish black	3.5–4.0	4.1–4.3	Softer than pyrite; with pyrite, galena, sphalerite.
Chert	SiO_2	No metal source.	White-gray	Dull	White	7.0	2.6	Impure, coarse-grained, opaque flint.
Chloanthite	$NiAs_2$ variable.	Ni—28.1% As—71.9%.	Tin white, steel gray.	Metallic	Grayish black	5.8	6.5	Granular or in crystals like pyrite. Often associated with erythrite. See erythrite.
Chromite	$FeO \cdot Cr_2O_3$	Cr—46.2%	Black	Vitreous	Dark brown	5.5	4.3–4.6	Grains may look like black glass. Often with serpentine.
Chrysoberyl	$BeOAl_2O_3$	BeO-19.8%	Green	Vitreous	White	8.5	3.7–3.8	Usually in crystals or worn pebbles. Gem varieties.
Chrysocolla	$CuOSiO_2 \cdot 2H_2O$.	Cu—36.2%	Blue, green	Vitreous, dull.	White	2.0–4.0	2.0–2.2	Adheres to dry tongue; important ore of copper.
Chrysolite	$(MgFe)_2SiO_4$	No metal source.	Green	Vitreous	White or yellowish.	6.5–7.0	3.3	In granular masses, glassy grains or crystals. Gem varieties.
Chrysotile	$H_4Mg_3Si_2O_9$	----------	White, greenish.	Metallic	White	1.7	2.2	Best asbestos. Masses of tough, usually parallel, slender fibers.
Cinnabar	HgS	Hg-86.2%	Red	Adamantine, submetallic.	Scarlet	2.0–2.5	8.0–8.2	Only important ore of mercury; tastes chalky.
Clausthalite	PbSe	Pb—72.4%	Lead gray	Metallic	Lead gray	2.8	8.0	Resembles granular galena.
Cobaltite	CoAsS	Co—35.5%	Tin white, steel gray.	Metallic	Grayish black	5.5	6.0–6.3	Granular or in crystals like pyrite Often with erythrite. See erythrite
Colemanite	$Ca_2B_6O_{11} \cdot 5H_2O$.	No metal source.	White, yellowish.	Brilliant, vitreous.	White	4.0–4.5	2.4	Usually occurs as geodes; brittle.
Columbite	$(FeMn)(CbTa)_2O$.	Variable—Ta_2O_5 3.3 to 31.5%.	Iron black	Submetallic	Dark red, black.	6.0	6.3	Brittle; nearly pure niobate.
Copper	Cu	Cu—100%	Copper red	Metallic	Copper-red	2.8	8.8	Tarnishes easily; malleable.
Corundum	Al_2O_3	Al—52.9%	All colors	Vitreous, adamantine.	White	9.0	3.9–4.1	In 6-sided crystals and masses that may break in three directions at nearly 90°. Gem varieties.
Cosalite	$Pb_2Bi_2S_5$	Pb—41.8% Bi—42.1%.	Lead gray	Metallic	Black	2.8	6.5	In quartz veins; with pyrite, sphalerite.
Covellite	CuS	Cu—66.5%	Blue	Submetallic	Black	1.5–2.0	4.6	Platy or granular massive. Turns purple when moistened.
Crocidolite	$NaFe(SiO_3)_2 \cdot FeSiO_3$.	No metal source.	Blue to green	Silky, dull	Like color	4.0–5.0	3.2–3.3	Fibrous masses; like asbestos, valuable.
Crocoite	$PbCrO_4$	Pb—64.1% Cr—16.1%.	Red	Adamantine	Orange yellow	2.5	6.0	Found with quartz, galena, vanadinite.
Cryolite	Na_3AlF_6	Al—13% F—54.4%.	Snow white	Greasy to vitreous.	White	2.5	3.0	Appearance, hardness are distinctive.
Cuprite	Cu_2O	Cu—88.8%	Red	Adamantine to dull.	Red	3.5–4.0	5.9–6.2	Oxidized mineral. Often in crystals—usually cubical.
Cyanite (or kyanite).	Al_2SiO_5	Al—33.3%	White, to blue or green.	Vitreous, pearly.	----------	4.0–7.0	3.6	Bladed crystals with flat cleavage surfaces that are easily scratched longitudinally but not transversely.
Descloizite	$4RO.V_2O_5.H_2O$.	Variable—V_2O_5.	Red, brown, black.	Greasy	Orange	3.5	6.0	Associated with vanadinite.
Diamond	C	C—100%	White, gray	Adamantine, greasy.	Ash gray	10.0	3.5	Occurs in crystals (usually rounded octahedrons) in a basic igneous rock, and in placers. Gem varieties.
Diaspore	$Al_2O_3 \cdot H_2O$	Al_2O_3—85%	Many colors	Vitreous	White	6.5–7.0	3.4	Occurs in thin scales; very brittle.
Diatomaceous earth.	$SiO_2 \cdot nH_2O$	----------	Yellow to brown.	Vitreous	White to gray	2.0	2.2	Roughens glass. Uniformly very fine texture and light in weight.
Dolomite	$CaMg(CO_3)_2$	CaO—30.4% MgO—21.9%.	White, gray, pink, yellow.	Vitreous, pearly.	White	3.5–4.0	2.8–2.9	Effervesces vigorously in any condition of muriatic acid except cold dilute. Like calcite, but common in warped rhombohedrons.

Name	Formula	Percent metal	Color	Lustre	Streak	Hardness	Specific gravity	Characteristics—occurrence
Enargite	$3Cu_2S\cdot As_2S_5$	Cu—48.4%	Iron black	Metallic	Black	3.0	4.4	Color and streak both black; prismatic cleavage.
Epidote	$Ca_2(AlOH)(AlFe)_2(SiO_4)_3$.	No metal source.	Green	Vitreous, dull.	White	6.0–7.0	3.2–3.5	Brittle; usually granular.
Epsom salt	$MgSO_4\cdot 7H_2O$	Mg—9.9%	White	Vitreous	White	2.3	1.7	Tastes bitter and saline; in mineral waters.
Erythrite	$Co_3As_2O_8\cdot 8H_2O$.	Co—29.5%	Usually pink, gray.	Pearly	Paler than color.	1.5–2.5	3.0	Deposits of secondary origin; with cobalt ores.
Ferberite	$FeWO_4$	W—60.6%	Brown, black, gray.	Metallic	----	5.0–5.5	7.2–7.5	Found with other tungsten ores.
Fluorite	CaF_2	F—48.9%	All colors	Vitreous	White	4.0	3.0–3.3	Octahedral cleavage; brittle.
Franklinite	$(ZnFeMn)O\,(FeMn)_2O_3$.	Zn—14.2% Mn—35.7%	Iron black	Metallic	Brown to black.	5.5–6.5	5.2	Usually associated with zincite; sometimes magnetic.
Galena	PbS	Pb—86.6%	Lead gray	Metallic	Lead gray	3.0	7.4–7.6	Very brittle; cubic cleavage.
Garnet	Various	No metal source.	Red, brown yellow.	Vitreous	White	6.5–7.5	3.2–4.3	Often in complete dodecahedral crystals, in schists or limestone. Gem varieties.
Garnierite	$H_2(NiMg)SiO_4$.	Ni—25% to 30%.	Green	Dull, greasy	Greenish white.	2.0–4.0	2.4	Amorphous; source of nickel; with serpentine, chromite.
Genthite	$2NiO,2MgO,3SiO_2\cdot 6H_2O$.	Ni—22.6%	Green	Dull, greasy	Greenish white.	2.0–4.0	2.4	Similar to garnierite.
Gibbsite	$Al(OH)_3$	Al—34.6%	White, green	Pearly	----	2.0–3.5	2.4	Occurs under same conditions as bauxite.
Gold	Au	Au—100%	Golden	Metallic	Golden yellow	2.8	15.6–19.3	Malleable and sectile. Does not tarnish.
Graphite	C	C—100%	Black	Dull, submetallic.	Dark gray, iron black.	1.0–2.0	2.2	Soft; marks paper; feels greasy; often impure.
Greenockite	CdS	Cd—77.7%	Yellow	Adamantine	Yellow to red	3.0–3.5	5.0	Usually occurs as coating on zinc minerals.
Grossularite	$Ca_3Al_2(SiO_4)_3$	No metal source.	White, green, yellow.	Vitreous	White	6.5–7.5	3.4–3.7	Often imbedded in mica and schists; limestones. Variety of garnet. See Garnet.
Gypsum	$CaSO_4\cdot 2H_2O$	CaO—32.6%	White, red	Vitreous	White to gray	1.5–2.0	2.3	Earthy, fibrous, scaly, and crystals with perfect cleavage in one direction.
Halite	$NaCl$	Na—39.4%	White	Vitreous	White	2.5	2.1–2.6	Natural table salt. Perfect cubical cleavage.
Halloysite	$H_4Al_2O_3\cdot 2SiO_2\cdot H_2O$.	No metal source.	White, green, blue, red.	Pearly, waxy, dull.	----	1.0–2.0	2.0–2.2	Often occurs in veins of ore as secondary product.
Hausmannite	Mn_3O_4	Mn—72%	Black, brown.	Metallic	Brown	5.3	4.7	Associated with other manganese minerals.
Hematite	Fe_2O_3	Fe—70%	Brown, red, black.	Metallic, dull, submetallic.	Red, brown	5.5–6.5	4.9–5.3	Becomes magnetic upon heating under reducing conditions.
Hessite	Ag_2Te	Ag—63%	Gray	Metallic	Black	2.5–3.0	8.3–8.9	With chalcopyrite, pyrite, and sphalerite.
Horneblende	Variable	Variable	White, green, black.	Vitreous	White	5.0–6.0	3.2	Crystals have 6-sided or diamond-shaped cross sections. Two perfect cleavages at angle of about 124°.
Huebnerite	$MnWO_4$	Mn—18.1% W—60.7%	Brown	Submetallic	Yellowish brown.	5.0–5.5	7.2–7.5	Usually in bladed aggregates with rough, flat parting, in quartz.
Hydrozincite	$ZnCo_3\cdot 2Zn(OH)_2$.	Zn—59.5%	White, gray, yellow.	Dull	White	2.0–2.5	3.6–3.8	Usually associated with other zinc ores.
Hypersthene	$(FeMg)SiO_3$	No metal source.	Black	Pearly	Gray	5.0–6.0	3.5	Occurs in foliated or platy masses.
Ilmenite	FeT O_3	Ti—C1.6%	Iron black	Metallic, submetallic.	Brown	5.0–6.0	4.5–5.0	Magnetic; with pyrite, horneblende, feldspars.
Iodyrite	AgI	Ag—46%	Yellow, green	----	----	3.0–4.0	5.6–5.7	Usually in thin plates; rare.
Iridium	Variable	Alloy—100%	White	Metallic	Gray	6.7	22.7	With platinum and allied metals.
Iridosmene	IrC (xhPtRu).	Alloy—100%	Tin white	Metallic	Gray	6.0–7.0	19.3–21.1	Rare metals alloy.
Jamesonite	$2PbS\cdot Sb_2S_3$	Pb—50.8% Sb—29.5%	Gray	Metallic	Grayish black	2.0–3.0	5.5–6.0	Usually in parallel or divergent aggregates of narrow blades. Sometimes in hair- or needle-like crystals.

Name	Formula	Percent metal	Color	Lustre	Streak	Hardness	Specific gravity	Characteristics—occurrence
Jefferisite	Variable	Variable	Yellowish brown.	Pearly	White	1.5	2.3	A mica with flexible but not elastic cleavage plates that puffs out greatly when heated.
Kainite	$MgSO_4 \cdot KCl \cdot 3H_2O$.	KCl—30.0%	White to red	Vitreous		2.8	2.1	See Cyanite.
Kaolinite	$H_4Al_2Si_2O_9$	Al_2O_3—39.5%	White, yellow	Pearly	Same as color	2.0–2.5	2.6	Widespread; earthy odor; clay.
Kermesite	Sb_2S_2O	Sb—75.3%	Cherry	Adamantine, metallic.	Brownish red	1.3	4.6	Occurs with stibnite.
Kieserite	$MgSo_4 \cdot H_2O$	Mg—17.6%	White, yellow	Vitreous		3.3	2.6	Often with gypsum and carnallite.
Lepidolite	KLi [Al(OHF)$_2$] Al(SiO$_3$)$_3$.	Small amount of Li.	Red, lilac, white.	Pearly	White	3.0	2.8–3.3	A mica with flexible, elastic cleavage plates. Usually in pegmatites.
Leucite	$KAl(SiO_3)_2$	K_2O—21.5%. Al_2O_3—23.5%.	Gray	Vitreous, dull.	White	5.5–6.0	2.5	Complete trapezohedral crystals in igneous rock.
Limestones	Chiefly $CaCO_3$.	Ca—40%	Variable	Dull	White	3.0	2.7	Eliminate this heading since limestone is a rock, not a mineral.
Limonite	$2Fe_2O_3 \cdot 3H_2O$	Fe—59.9%	Brown, yellow.	Submetallic	Yellowish brown.	5.0–5.5	3.6–4.0	Massive, fibrous or porous; magnetic after fusing.
Linnaeite	Co_3S_4	Co—58.0%	Steel gray	Metallic	Blackish gray	5.5	4.8–5.0	Copper red tarnish; in gneiss with chalcopyrite.
Livingstonite	$HgS \cdot 2Sb_2S_3$	Hg—22.0%	Lead gray	Metallic	Red	2.0	4.81	Resembles stibnite; fuses easily.
Magnesite	$MgCO_3$	Mg—28.9%	White to black.	Vitreous	White	4.0–4.5	3.1	Effervesces vigorously in hot, concentrated muriatic acid.
Magnetite	$FeO \cdot Fe_2O_3$	Fe—72.4%	Iron black	Metallic, submetallic.	Black	5.5–6.5	5.2	Strongly magnetic; many associations.
Malachite	$CuCO_3 \cdot Cu(OH)_2$.	Cu—57.5%	Green	Silky	Green	3.5–4.0	4.0	Oxidized mineral. Effervesces vigorously in muriatic acid of any strength or temperature.
Manganite	$Mn_2O_3 \cdot H_2O$	Mn—62.5%	Iron black, steel gray.	Metallic, submetallic.	Brown	4.0	4.2–4.4	Hardness and streak are distinctive.
Marble	Chiefly $CaCO_3$.	Ca—40%	Variable	Vitreous, earthy.	White, gray	3.0	2.7	Granular calcite. See calcite.
Marcasite	FeS_2	Fe—46.6%	Yellow	Metallic	Grayish, brown, black.	6.0–6.5	4.9	Deposited near earth's surface. Often in tabular crystals in coxcomb-like groups.
Marmatite	(ZnFe)S, variable.	Zn—46.5% to 56.9%.	Yellow, brown, black.	Adamantine	Brownish	5.0	3.9–4.2	Closely allied with galena; common zinc ore.
Melaconite	CuO	Cu—79.9%	Black	Earthy, metallic.		3.0–4.0	6.5	
Melilite	$Ca_{12}Al_4Si_9O_{36}$		White, yellow, green, brown.	Vitreous	White	5	2.9–3.1	Formed from magmas; common in portland cement.
Mercury	Hg	Hg—100%	Tin white	Metallic			13.59	Liquid; rarely found in metallic state.
Metacinnabarite	HgS	Hg—86.2%	Grayish black.	Metallic	Black	3	7.7	Found in upper portions of mercury deposits.
Millerite	NiS	Ni—64.8%	Yellow	Metallic	Greenish black	3.0–3.7	5.3–5.7	Crusts with a radiating texture and hair- or needle-like crystals.
Mimetite	$(PbCl)Pb_4As_3O_{12}$.	Pb—69.7%	Yellow to brown.	Resinous	White	3.5	7.0–7.3	Often in crystals with 6-sided cross sections, which may taper.
Molybdenite	MoS_2	Mo—60%	Lead gray	Metallic	Greenish gray	1.0–1.5	4.7–4.8	Feels greasy. Makes light greenish yellow mark on glazed paper.
Molybdite	MoO_3	Mo—66.67%	Yellow	Adamantine, pearly.		1.5	4.5	Occurs with molybdenite.
Monazite	$(CeLaDy)PO_4 \cdot ThSiO_4$.	ThO_2—9%	Yellow, brown.	Resinous	White	5.0–5.5	4.9–5.3	Rounded grains; with gold, chromite, iron.
Mottramite	Variable	Variable	Black, yellow	Resinous	Yellow	3	5.8	A vanadate of lead and copper.
Muscovite	$H_2KAl_3(SiO_4)_3$	Variable	Yellowish white.	Vitreous, pearly.	White	2.0–2.5	2.8–3.0	Cleaves easily into very thin, elastic, flexible leaves.
Naumannite	$(Ag_2Pb)Se$	Ag—43.0%	Iron black	Metallic	Iron black	2.5	8	Malleable; in cubic crystals; selenide of silver and lead.
Nephelite	$NaAlSiO_4$	No metal source.	White, yellow	Vitreous, greasy.	White	5.5–6.0	2.5–2.7	Widely distributed in igneous rocks; usually massive.

Name	Formula	Percent metal	Color	Lustre	Streak	Hardness	Specific gravity	Characteristics—occurrence
Niccolite	NiAs	Ni—44.1%. As—55.9%.	Copper red	Metallic	Brownish black.	5.0-5.5	7.3-7.7	Often found with a green coating; brittle; compact.
Nitre	KNO_3	K—38.6%. N—13.9%.	White	Vitreous	White	2	2.1	Tastes saline and cooling; salt petre.
Olivine	$(MgFe)_2SiO_4$	No metal source.	Green	Vitreous	White or yellowish.	6.5-7.0	3.3	Same as Chrysolite.
Opal	$SiO_2 \cdot nH_2O$	No metal source.	All colors	Greasy, vitreous.	White	5.5-6.5	1.9-2.3	Very smooth, curving fracture.
Orpiment	As_2S_3	As—61%	Lemon yellow.	Resinous	Lemon yellow	1.5-2.0	3.5	Usually associated with realgar; seldom valuable.
Orthoclase	$KAlSi_3O_8$	Al_2O_3—18.4%	Red, gray, yellow, white.	Vitreous, dull.	White	6.0-6.5	2.5-2.6	Common, often pinkish igneous rock mineral with two smooth right angled cleavages.
Pentlandite	(FeNi)S	Fe—42.0%. Ni—22.0%.	Yellow-bronze.	Metallic	Black	3.5-4.0	4.6-5.0	Associated with pyrrhotite, millerite, chalcopyrite, etc.
Petzite	$(AuAg)_2Te$	Au—25.5%. Ag—42%.	Gray to black.	Metallic	Gray	2.5	9.1	A rare but valuable ore of gold and silver; often tarnishes.
Phosphate rock	$Ca_3(PO_4)_2$	P_2O_5—31.1%	Gray	Dull	Gray	5	3.2	Occurs in massive deposits.
Platinum	Pt	Pt—100%	Tin white, steel white.	Metallic	Shiny gray	4.5	17.0	Sometimes magnetic; with gold and chromite.
Polianite	MnO_2	Mn—63.2%	Steel gray, iron gray.	Metallic	Black	6.3	4.9	Looks like pyrolusite, but harder and dryer; rare.
Polybasite	$9Ag_2S \cdot Sb_2S_3$	Ag—75.6%. Sb—9.4%.	Iron black	Metallic	Black	2.0-3.0	6.0-6.2	With chalcopyrite, calcite, pyrargyrite, stephanite.
Powellite	$Ca(Mo \cdot W)O_4$	Variable	Greenish yellow.	Resinous		3.5	4.5	Often associated with scheelite.
Proustite	$3Ag_2S \cdot As_2S_3$	Ag—65.5%	Scarlet	Adamantine, dull.	Scarlet	2.0-2.5	5.6	Usually associated with other silver ores.
Psilomelane	$MnO_2 \cdot H_2O \cdot K_2BaO_2$.		Black	Submetallic, dull.	Black, brownish black.	5.0-6.0	3.7-4.7	Either powdery (Wad) or has smooth, curving fracture.
Pyrargyrite	$3Ag_2S \cdot Sb_2S_3$	Ag—60%. Sb—22.2%.	Black, reddish.	Adamantine, metallic.	Purplish red	2.5	5.8-5.9	Often associated with argentite and prousite.
Pyrite	FeS_2	Fe—46.7%	Brass yellow	Metallic	Greenish, brownish black.	6.0-6.5	5.0	Often in crystals that are cubical or show prominently a form with 5-sided faces.
Pyrolusite	MnO_2	Mn—63.2%	Black, dark gray.	Metallic, dull	Black, bluish black.	1.0-2.5	4.8	Soils fingers; hardness and streak are distinctive.
Pyromorphite	$Pb_5Cl(PO_4)_3$	Pb—76.4%	Yellow	Greasy, adamantine.	White, yellowish white.	3.5-4.0	5.9-7.1	Alteration product of lead minerals. Occurs like mimetite.
Pyrope	$Mg_3Al_2(SiO_4)_3$	No metal source.	Red	Vitreous, resinous.	White	6.5-7.6	3.7	Variety of garnet. See garnet.
Pyrophyllite	$HAl(SiO_3)_2$	Al_2O_3—28.3%	White, brown	Pearly, dull	White	1.0-2.0	2.8-2.9	Feels greasy or soapy.
Pyroxene	$Ca(AlMg MnFe)(SiO_3)_2$.	No metal source.	Green	Vitreous, dull	White to green	5.0-6.0	3.3	Commonly in igneous rocks in square or 8-sided crystals.
Pyrrhotite	Fe_5S_6 to $Fe_{16}S_{17}$.	Fe—61.5% variable.	Brownish yellow.	Metallic	Grayish black	3.5-4.6	4.6	Only magnetic sulphide and therefore distinctive.
Quartz	SiO_2	Si—46.9%	Colorless, all colors.	Vitreous	White	7.0	2.65-2.66	Common in 6-sided prisms with pointed terminations. Gem varieties.
Realgar	AsS	As—70.1%	Orange	Resinous	Orange	1.5-2.0	2.6	Usually associated with Orpiment; flexible.
Rhodochrosite	$MnCO_3$	MnO—61.7%	Usually red	Vitreous, pearly.	White	3.5-4.5	3.5-3.6	Blackens on exposure. Effervesces vigorously in hot, concentrated muriatic acid.
Rhodonite	$MnSiO_3$	Mn—42.0%	Brownish red	Vitreous, dull	White	5.5-6.5	3.4-3.7	With calcite, Zincite, tetrahedrite.
Roscoelite	$H_8K(MgFe)(AlV)_4(SiO_3)_{12}$.	Variable	Brown	Pearly		Soft	2.9	Vanadium mica in which vanadium replaced aluminum.
Rutile	TiO_2	Ti—60%	Brown, red, black.	Adamantine, submetallic.	Light brown	6.0-6.5	4.2	Commonly in crystals with longitudinally grooved faces, or needle- or hair-like.
Scheelite	$CaWO_4$	W—63.9%	White yellow.	Vitreous, adamantine.	White	4.5-5.0	5.9-6.1	Weight, hardness, and uneven fracture are distinctive.

Name	Formula	Percent metal	Color	Lustre	Streak	Hardness	Specific gravity	Characteristics—occurrence
Senarmontite	Sb_2O_3	Sb—83.6%	Colorless, grayish.	Vitreous, dull.	White	2	5.3	Formed by oxidation of stibnite.
Serpentine	$H_4Mg_3Si_2O_9$	Mg—43%	Green, blackish or yellow, white.	Wax-like, silky.	White	4.0	2.5-2.6	Feels smooth and sometimes slightly greasy.
Siderite	$FeCO_3$	Fe—48.3%	Brown, gray	Vitreous, pearly, dull.	White to yellow	3.5-4.0	3.9	Magnetic after heating. Effervesces vigorously in hot, concentrated muriatic acid.
Silver	Ag	Ag—100%	Silver white	Metallic	Silver-white	2.8	10.5	Malleable and sectile. Tarnishes quickly.
Smaltite	$CoAs_2$	CO—28.2% As—71.8%.	Tin white, steel gray.	Metallic	Grayish black	5.5-6.0	5.7-6.8	Granular or in crystals like pyrite. Often with erythite. See erythite.
Smithsonite	$ZnO{\cdot}CO_2$	Zn—52%	Green, gray, blue.	Vitreous, dull	White, grayish	5.0	4.3-4.5	Effervesces vigorously in any strength or temperature or muriatic acid except cold dilute.
Soda nitre	$NaNO_3$		White, reddish brown; colorless.	Vitreous	White	1.8	2.3	Taste-cooling; incrustations in beds; massive.
Sperrylite	$PtAs_2$	Pt—56.6% As—43.4%.	Tin white	Metallic, brilliant.	Black	6.5	10.6	Found with gold-quartz, covellite, limonite.
Spessartite	$Mn_3Al_2(SiO_4)_3$	No metal source.	Purplish, red	Vitreous		6.5-7.5	4.0-4.3	A form of garnet.
Sphalerite	ZnS	Zn—67.1%	Brown, yellow, reddish, black.	Submetallic, resinous.	Light brown, yellow.	3.5-4.0	3.9-4.1	Cleaves smoothly in six directions a angles of 60°, 90°, and 120°.
Spinel	$MgOAl_2O_3$	Al_2O_3—71.8% MgO—28.2%.	Black, gray, brown, red.	Vitreous, dull.	White to gray	8.0	3.5-4.1	Massive or in octahedral crystals. Gem varieties.
Spodumene	$LiAl(SiO_3)_2$	Al_2O_3—27.4% Li_2O—8.4%.	White, grayish.	Vitreous, dull.	White	6.5-7.0	3.1-3.2	Occurs usually in platy masses or chunky crystals, sometimes huge. Gem varieties.
Stannite	$Cu_2S{\cdot}FeS{\cdot}SnS_2$.	Sn—27.5% Cu—29.5%.	Steel gray, iron black.	Metallic	Blackish	4.0	4.5	Has appearance of bronze.
Stephanite	$5Ag_2S{\cdot}Sb_2S_3$	Ag—68.5%	Iron black	Metallic	Iron black	2.0-2.5	6.2-6.3	Associated with other silver ores.
Stibnite	Sb_2S_3	Sb—71.8%	Lead gray	Metallic	Lead gray, black.	2.0	4.5-4.6	Cleavage surfaces marked transversely with parallel lines.
Strontianite	$SrCO_3$	Sr—59.3%	Yellow to brown, green.	Vitreous, greasy.	White to gray	3.5-4.0	3.7	Effervesces vigorously in dilute cold, but not in concentrated cold, muriatic acid. Effervescing fragment colors alcohol flame red.
Sulfur	S	S—100%	Yellow	Greasy, adamantine.	Pale yellow	2.0	2.0	Burns with a characteristic odor.
Sylvanite	$(AuAg)Te_2$	Au—24.5% Ag—13.4%.	White to steel gray.	Metallic	Same as color	1.5-2.0	7.9-8.3	Occurs often in small, bladed or pris matic crystals.
Sylvite	KCl	K—52.4%	White, yellowish red.	Vitreous	White	2.0	1.98	Taste—saline; soluble; bitter.
Talc	$H_2Mg_3(SiO_3)_4$	Mg—19.2% Si—29.6%.	Green to white.	Pearly	White	1.0-1.5	2.7-2.8	Common; feels greasy; extensive beds.
Tantalite	$FeTa_2O_6$	Variable Ta_2O_5—65.6%.	Iron black	Submetallic, greasy, dull.	Reddish brown.	6.3	5.3-7.3	Iron and manganese content variable; with columbite.
Tennantite	$Cu{\cdot}As_2S_7$ variable.	Cu—57.5% variable.	Steel gray, iron black.	Metallic	Black, reddish brown	3.0-4.5	4.4-4.5	Occurs granular massive or in tetrahedral crystals.
Tenorite	CuO	Cu—79.9%	Black	Metallic		3.0	5.8-6.3	Sublimation product in volcanic regions.
Tephroite	Mn_2SiO_4	No metal source.	Red, ash gray	Vitreous		6.5-7.0	4.0-4.1	Rarely in small crystals; like chrysolite.
Tetradymite	$Bi_2(TeS)$	Variable	Pale steel gray	Metallic		1.8	7.4	Soils paper; found in gold-quartz and igneous rocks.
Tetrahedrite	$4Cu_2S{\cdot}Sb_2S_3$	Cu—52.1% Sb—24.8%.	Gray to black	Metallic	Black	3.0-4.5	4.4-5.1	Like tennantite but has a darker streak—not reddish.
Titanite	$CaTiSiO_5$	TiO_2—40.8%	Brown, gray, yellow, green.	Adamantine	White	5.0-5.5	3.4-3.6	Occurs in platy massive or in wedge-shaped crystals.

Name	Formula	Percent metal	Color	Lustre	Streak	Hardness	Specific gravity	Characteristics—occurrence
Topaz	$(AlF)_2SiO_4$	No metal source.	Many	Vitreous		8.0	3.4–3.6	Often in prismatic crystals with diamond-shaped cross sections and a perfect transverse cleavage. Gem varieties.
Tourmaline	$[(NaLiK)_6(MgFeCa)_3(AlCrFe)_3B_3SiO_5]$	No metal source.	Black, brown, and many others.	Vitreous to resinous.	White	7.0–7.5	3.0–3.2	Usually in prismatic crystals with spherical triangular cross sections. Gem varieties.
Tremolite	$CaMg_3(SiO_3)_4$	No metal source.	White to dark gray.	Silky	White	5.0–6.0	2.9–3.4	Perfect cleavages in two directions at an angle of about 124°.
Triphyllite	$LiFePO_4$	Li—4.4%	Greenish gray, bluish gray.	Vitreous, resinous.	White to grayish white.	4.8	3.5	A phosphate or iron, manganese and lithium.
Ullmannite	NiSbS	Ni—27.6% Sb—57.3%.	Steel gray to white.	Metallic	Grayish	5.3	6.4	With galena and chalcopyrite.
Uraninite	UO_2, UO_3 variable.	Radium source.	Gray, green, brown.	Submetallic to greasy.	Black, gray, green.	5.5	9.0–9.7	Of primary and secondary origin; no definite formula.
Uvarovite	$Ca_3Cr_2(SiO_4)_3$	No metal source.	Green	Vitreous	White	6.5–7.5	3.5	A form of garnet.
Valentinite	Sb_2O_3	Sb—83.5%	White	Adamantine to pearly.	White	2.5–3.0	5.6	An oxidized mineral.
Vanadinite	$(PbCl)Pb_4(VO_4)_3$.	Variable	Red, brown, yellow.	Resinous	White or yellow	2.7–3.0	6.6–7.1	Like mimetite, but crystals usually very sharp and do not taper.
Vermiculite	$3MgO.(FeAl)_2O_3 3SiO_2$.	Variable	Grayish	Talc-like	Uncolored	1.5	2.7	Becomes worm-like threads upon heating—exfoliates.
Willemite	Zn_2SiO_4	Zn—58.5%	Green, yellow, brown.	Vitreous, dull.	White or grayish.	5.5	3.9–4.2	Massive to granular; valuable zinc ore.
Witherite	$BaCO_3$	BaO—77.7%	Yellow, brown.	Vitreous, pearly.	White	3.4	4.4	Reacts like strontianite in muriatic acid, but effervescing fragment colors alcohol flame light yellowish green.
Wolframite	$(FeMn)WO_4$	W—51.3%	Gray, brown, black.	Submetallic	Reddish-brown.	5.0–5.5	7.2–7.5	Differs from huebnerite in streak.
Wulfenite	$PbMoO_4$	Pb—56.4% Mo—26.2%.	Yellow, grayish.	Resinous, adamantine.	White	3.0	6.8	In square crystals, usually tabular with beveled edges.
Zaratite	$NiCO_3.2Ni(OH)_2.4H_2O$.	Ni—46.8%	Green	Vitreous	Light green	3	2.6	Emerald nickel; amorphous.
Zincite	ZnO	Zn—80.3%	Red, yellow	Sub-adamantine.	Orange yellow	4.0–4.5	5.4–5.7	Associated with other zinc ores.
Zircon	$ZrSiO_4$	ZrO—67.2%	Yellow, gray	Adamantine	Colorless	7.5	4.2–4.7	In sharp crystals with square cross sections and as pebbles. Gem varieties.

Common Hypogene, Supergene, and Oxidized Ore Minerals

Metal	Minerals generally hypogene	Minerals generally supergene	Minerals generally originating in oxidized zone
Copper	Chalcopyrite	Chalcocite	Native copper.
	Bornite	Sooty chalcocite*	Malachite.*
	Enargite*	Covellite	Brochantite.*
	Tetrahedrite*		Antlerite.*
	Tennantite*		Atacamite.*
			Azurite.*
			Chrysocolla.*
			Cuprite.*
			Tenorite.*
Silver	Tetrahedrite*	Native silver	Cerargyrite.*
	Tennantite*	Argentite	Embolite.*
		Pyrargyrite	Bromyrite.*
		Proustite	
		Stephanite	
		Polybasite	
		Pearcite	
Gold	Native gold	Native gold	Native gold(?).
	Gold tellurides*		
Zinc	Sphalerite	Wurtzite	Smithsonite.*
	Willemite*		Hemimorphite.*
			Hydrozincite.*
Lead	Galena*		Cerussite.*
			Anglesite.*
			Pyromorphite.*
			Leadhillite.
Iron	Pyrite*	Marcasite	Goethite.*
	Marcasite		Iron sulphates.*
	Pyrrhotite*		Hematite.
	Arsenopyrite*		
	Magnetite*		
	Hematite		
	Specularite*		
	Siderite		
Manganese	Rhodochrosite*		Psilomelane.
	Rhodonite*		Pyrolusite.
	Manganite(?)		Braunite.
	Alabandite*		
Nickel	Millerite	Bravoite(?)	Garnierite.*
	Pentlandite*		
	Niccolite*		

*Always hypogene or supergene or oxidized according to the column in which they are placed.

Heavy Minerals That May Be Found in Placer Gravels

Mineral	Chemical formula	Color	Specific gravity	Hardness	Remarks
Gold	Au(+Ag)	Gold-yellow	15.6-19.3	2.5	Very malleable and ductile.
Magnetite	Fe_3O_4	Iron-black	5.2	5.5-6.5	Shiny grains; strongly magnetic.
Ilmenite	$(Mg,Fe)TiO_3$	do	4.5-5	5-6	Only faintly magnetic; moves compass needle slightly.
Garnet	$R''_3R'''_2(SiO_4)_3$*	Red, brown, various	3.8	6.5-7.5	Vitreous luster; usually in rounded crystals (dodecahedron).
Zircon	$ZrSiO_4$	Brown, pale yellow, or colorless.	4.7	7.5	Adamantine luster.
Hematite	Fe_2O_3	Dark steel-gray to iron-black.	4.9-5.3	5.5-6.5	Particles usually smooth, rounded, often red-coated.
Chromite	$FeCr_2O_4$	Iron-black to brown-black.	4.1-4.9	5.5	Sometimes feebly magnetic; brown streak.
Olivine	$(Mg,Fe)_2SiO_4$	Olive-green	3.3-3.4	6.5-7	Good cleavage; vitreous luster; clear to translucent.
Epidote	$HCa_2(Al,Fe)_3Si_3O_{13}$.	Pistachio-green	3.2-3.5	6-7	Distinct cleavage.
Pyrite	FeS_2	Pale brass-yellow	4.9-5.1	6-6.5	Usually cubic grains; brittle; metallic luster.
Monazite	$(Ce,La,Di)PO_4+ThO_2$.	Yellow	4.9-5.3	5-5.5	Resinous or greasy luster; usually in rounded grains.
Limonite	$2Fe_2O_3.3H_2O$	Dark brown	3.6-4.0	5-5.5	Yellow-brown streak.
Rutile	TiO_2	Red-brown to red	4.2	6-6.5	Distinct cleavage; metallic-adamantine luster.
Platinum	Pt (usually also Fe, Ir, Os).	Whitish steel	16.5-18	4-4.5	Malleable; sometimes scales and grains.
Iridium	Ir (also Pt, etc.)	Silver-white, yellow tarnish.	22.6-22.8	6-7	Generally in angular grains; no cleavage.
Iridosmine	Ir,Os	Tin-white to light steel-gray.	19.3-21.1	6-7	Usually flat grains; slightly malleable to brittle; good cleavage.
Wolframite	$(Fe,Mn)WO_4$	Black, dark gray	7.2-7.5	5-5.5	Submetallic luster; good cleavage in one plane.
Cinnabar	HgS	Red	8-8.2	2-2.5	Scarlet streak.
Sheelite	$CaWO_4$	White, pale yellow, brown, or gray.	5.9-6.1	4.5-5	Adamantine, greasy luster; translucent.
Cassiterite	SnO_2	Brown or black	6.8-7.1	6-7	Brittle; rounded grains.
Corundum, Sapphire, Ruby	Al_2O_3	Blue, red, yellow, brown.	3.9-4.1	9	Adamantine to vitreous luster.
Diamond	C	White, colorless, pale	3.5	10	Adamantine or greasy luster.
Mercury	Hg	Tin-white	13.6		Small opaque fluid; silvery globules.
Amalgam	Hg, Ag, Au	Silver-white	13-14		Brittle to malleable; rubs silvery coat on copper.
Silver	Ag	Silver-white	10.1-11.1	2.5-3	Malleable and ductile; tarnishes black.
Copper	Cu	Copper-red	8.8-8.9	2.5-3	Ductile; malleable.
Bismuth	Bi	Silver-white	9.8	2.5	Sectile; brittle; metallic luster.
Columbite-tantalite	$(Fe,Mn)(Nb,Ta)_2O_6$	Iron-black to gray or brown-black.	5.3-7.3	6	Brilliant to submetallic luster; often irridescent; brittle; good cleavage.
Quartz	SiO_2	Colorless	2.6	7	No cleavage; vitreous to greasy luster.
Feldspars	Silicates of K, Na, Ca, Al, etc.	Colorless, white, pale yellow, or pink.	2.5-2.7	6-6.5	Good cleavage; vitreous luster.
Galena	PbS	Lead-gray	7.4-7.6	2.5-2.7	Metallic luster; lead-gray streak; perfect cubic cleavage; friable.
Cerussite	$PbCO_3$	Colorless or white	6.5	3-3.5	Adamantine luster.

*R″=Ca, Mg, Mn, or Fe; R‴=Fe, Al, or Cr.

QUARTERLY OF THE COLORADO SCHOOL OF MINES
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H-3890-1 - HANDBOOK FOR MINERAL EXAMINERS

CLASSIFICATION OF IGNEOUS ROCKS

Russell B. Travis

ESSENTIAL MINERALS	POTASH FELDSPAR > 2/3 TOTAL FELDSPAR			POTASH FELDSPAR 1/3–2/3 TOTAL FELDSPAR		
	QUARTZ > 10%	QUARTZ < 10% FELDSPATHOID < 10%	FELDSPATHOID > 10%	QUARTZ > 10%	QUARTZ < 10% FELDSPATHOID < 10%	FELDSPATHOID > 10%
CHARACTERIZING ACCESSORY MINERALS	CHIEFLY: HORNBLENDE, BIOTITE, PYROXENE, MUSCOVITE ALSO: SODIC AMPHIBOLES, AEGIRINE, CANCRINITE, SODALITE, TOURMALINE			CHIEFLY: HORNBLENDE, BIOTITE, PYROXENE ALSO: SODIC AMPHIBOLES, AEGIRINE		
COLOR INDEX	10	15	20	20	25	30
AVERAGE CHEMICAL COMPOSITON (DALY) SiO_2	71.5	60.4	56.0	66.8	57.0	54.1
Al_2O_3	14.0	17.0	19.2	15.8	17.1	21.0
Fe_2O_3	1.5	2.7	2.9	2.3	3.4	1.8
FeO	1.4	2.9	1.6	1.3	3.6	3.3
MgO	0.6	1.8	0.6	1.0	2.3	1.1
CaO	1.6	3.7	2.0	2.8	5.4	3.2
Na_2O	3.4	4.2	8.5	3.7	4.7	6.2
K_2O	4.3	5.1	5.3	4.2	3.7	5.9
PHANERITIC — EQUIGRANULAR Batholiths, lopoliths, stocks, large laccoliths, thick dikes, and sills.	**GRANITE** ALASKITE—few dark minerals GRAPHIC GRANITE—graphic texture ALKALI GRANITE—abundant albite and sodic amphibole or pyroxene CHARNOCKITE—with orthopyroxene LUXULLIANITE—tourmalinized	**SYENITE** QUARTZ SYENITE—a litle quartz ALKALI SYENITE—no plagioclose except albite PULASKITE—a little nepheline NORDMARKITE—a little quartz LARVIKITE—with "blue" feldspar SHONKINITE—abundant FeMg minerals	**NEPHELINE SYENITE** LEUCITE SYENITE—pseudoleucite only feldspathoid SODALITE SYENITE—sodalite only feldspathoid FOYAITE—abundant fledspar MALIGNITE—abundant FeMg minerals DITROITE—with nepheline and sodalite	**QUARTZ MONZONITE** (ADAMELLITE)	**MONZONITE**	**NEPHELINE MONZONITE**
PORPHYRITIC — PHANERITIC GROUNDMASS Laccoliths, dikes, sills, plugs, small stocks, margins of larger masses.	**GRANITE PORPHYRY**	**SYENITE PORPHYRY**	**NEPHELINE SYENITE PORPHYRY**	**QUARTZ MONZONITE PORPHYRY**	**MONZONITE PORPHYRY**	**NEPHELINE MONZONITE PORPHYRY**
PORPHYRITIC — APHANITIC GROUNDMASS Dikes, sills, laccoliths, surface flows, margins or larger masses, welded tuffs.	**RHYOLITE PORPHYRY**	**TRACHYTE PORPHYRY**	**PHONOLITE PORPHYRY**	**QUARTZ LATITE PORPHYRY**	**LATITE PORPHYRY**	**NEPHELINE LATITE PORPHYRY**
APHANITIC — MICROCRYSTALLINE Dikes, sills, surface flows, margins of larger masses, welded tuffs.	**RHYOLITE**	**TRACHYTE**	**PHONOLITE** LEUCITE PHONOLITE (Leucite trachyte)—leucite only feldspathoid TINGUAITE—abundant aegirine WYOMINGITE—leucite and phlogapite	**QUARTZ LATITE** (DELLENITE)	**LATITE** (TRACHY-ANDESITE)	**NEPHELINE LATITE**

ESSENTIAL MINERALS	PLAGIOCLASE FELDSPAR > 2/3 TOTAL FELDSPAR					
	POTASH FELDSPAR > 10% TOTAL FELDSPAR	POTASH FELDSPAR < 10% TOTAL FELDSPAR				
		SODIC PLAGIOCLASE		CALCIC PLAGIOCLASE		
	QUARTZ > 10%	QUARTZ > 10%	QUARTZ < 10% FELDSPATHOID < 10%	QUARTZ < 10% FELDSPATHOID < 10%		FELDSPATHOID > 10% PYROXENE > 10%
CHARACTERIZING ACCESSORY MINERALS	CHIEFLY: HORNBLENDE, BIOTITE, PYROXENE (IN ANDESITE) ALSO: PYROXENE FELDSPATHOID SODIC AMPHIBOLES			CHIEFLY: PYROXENE, URALITE, OLIVINE ALSO: HORNBLENDE, BIOTITE, QUARTZ, ANALCITE, AEGIRINE, SODIC AMPHIBOLES		
COLOR INDEX	20	20	25	50		60
AVERAGE CHEMICAL COMPOSITON (DALY) SiO_2	65.3	61.6	58.2	48.6		47.4
Al_2O_3	16.1	16.2	17.0	16.8		15.4
Fe_2O_3	2.1	2.5	3.2	4.8		4.9
FeO	2.3	3.8	3.7	6.0		5.4
MgO	1.7	2.8	3.5	5.1		5.0
CaO	3.9	5.4	6.3	8.9		9.7
Na_2O	3.8	3.4	3.5	3.7		3.8
K_2O	2.7	2.1	2.1	1.9		3.5
PHANERITIC — EQUIGRANULAR	**GRANODIORITE**	**QUARTZ DIORITE** (TONALITE)	**DIORITE**	**GABBRO** GABBRO—with clinopyroxene NORITE—with orthopyroxene OLIVINE GABBRO—with olivine TROCTOLITE—olivine and plagioclase only ANORTHOSITE—plagioclase only QUARTZ GABBRO—with quartz	**DIABASE** (Dolerite of British) Phaneritic diabasic texture, normally medium or fine-grained	**THERALITE** (ESSEXITE, NEPHELINE GABBRO) TESCHENITE—analcite only feldspathoid OLIVINE THERALITE—with olivine
PORPHYRITIC — PHANERITIC GROUNDMASS	**GRANODIORITE PORPHYRY**	**QUARTZ DIORITE PORPHYRY**	**DIORITE PORPHYRY**	**GABBRO PORPHYRY**		**THERALITE PORPHYRY**
PORPHYRITIC — APHANITIC GROUNDMASS	**DACITE PORPHYRY**		**ANDESITE PORPHYRY**	**BASALT PORPHYRY**		**TEPHRITE PORPHYRY**
APHANITIC — MICROCRYSTALLINE	**DACITE**		**ANDESITE**	**BASALT** OLIVINE BASALT—with olivine ANALCITE BASALT—with analcite QUARTZ BASALT—with quartz OCEANITE—with abundant olivine		**TEPHRITE** LEUCITE TEPHRITE—leucite only feldspathoid BASANITE—with olivine LEUCITE BASANITE—with olivine and leucite

ESSENTIAL MINERALS	LITTLE OR NO FELDSPAR		SPECIAL TYPES
	CHIEFLY PYROXENE AND/OR OLIVINE	CHIEFLY FERRO-MAGNESIAN MINERALS AND FELDSPATHOIDS	
CHARACTERIZING ACCESSORY MINERALS	CHIEFLY: SERPENTINE, IRON ORE ALSO: HORNBLENDE, BIOTITE	HORNBLENDE BIOTITE IRON ORE	
COLOR INDEX	95	55	
AVERAGE CHEMICAL COMPOSITON (DALY) SiO_2	41.1	42.0	
Al_2O_3	4.8	17.9	
Fe_2O_3	4.0	5.7	
FeO	7.1	5.7	
MgO	32.2	3.4	
CaO	4.4	10.3	
Na_2O	0.5	8.0	
K_2O	1.0	2.4	
PHANERITIC — EQUIGRANULAR	**PERIDOTITE** PERIDOTITE—clinopyroxene and olivine HARZBURGITE—orthopyroxene and olivine PICRITE—pyroxene and olivine with some plagioclase DUNITE—olivine only PYROXENITE—pyroxene only SERPENTINE (SERPENTINITE)—chiefly serpentine	MISSOURITE—pyroxene, olvine, and pseudoleucite UOLITE—pyroxene and nepheline FERGUSITE—pyroxene and pseudoleucite UNCOMPAHGRITE (MELILITE PYROXENITE)—pyroxene and melilite	**PEGMATITE**—phanerocrystalline, normally silicic, dike rock (or small irregular mass (having a conspicuously coarser texture than parent. **APLITE**—phanerocrystalline rock having sugary (fine-grained allotriomerphic-granular) texture. **LAMPROPHYRE**—dark dike rock with exclusive FeMg phenocrysts and or euhedral FeMg minerals in ground-mass.
PORPHYRITIC — PHANERITIC GROUNDMASS	**PERIDOTITE PORPHYRY** KIMBERLITE—peridotite porphyry or breccia		
PORPHYRITIC — APHANITIC GROUNDMASS	**LIMBURGITE PORPHYRY**		
APHANITIC — MICROCRYSTALLINE	**LIMBURGITE**	NEPHELINITE—pyroxene and nepheline LEUCITITE—pyroxene and leucite MELILITITE—pyroxene and melilite OLIVINE NEPHELINITE (NEPHELINE BASALT)—pyroxene, nephaline, and olivine. ETC.	**TRAP**—dark-colored aphanitic rock. **FELSITE**—light-colored aphanitic rock.

APHANITIC — GLASSY
Surface flows, margins of dikes and sills, welded tuffs.

OBSIDIAN—black
PITCHSTONE—resinous
VITROPHYRE—porphyritic
PERLITE—concentric fractures
PUMICE—finely cellular, light colored
SCORIA—coarsely cellular, dark colored

Normally it is not possible to determine the composition of these rocks. They are customarily designated by the names at the left of this column. Basic glass is rare so rocks named, except scoria, will normally be silicic. If the approximate composition (by close association) or silica content (by refractive index or analysis), can be determined, the name may be prefixed by the name of the appropriate aphanitic rock, for example, "trachyte obsidian," or "latite vitrophyre." In general, scoria is basic; basic absidian is called "tachylite"; and spherulitic tachylite is "variolite."

FREQUENCY OF OCCURRENCE:

This size type indicates **COMMON ROCKS.**
This size type indicates **UNCOMMON ROCKS.**
This size type indicates **RARE ROCKS.**

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CLASSIFICATION OF SEDIMENTARY ROCKS

By Russell B. Travis

TEXTURE	GRAIN SIZE < 1/256 mm.		GRAIN SIZE 1/256-2 mm.							GRAIN SIZE > 2 mm.		
	CRYSTALLINE, CLASTIC OR AMORPHOUS		CRYSTALLINE, CLASTIC, BIOCLASTIC, OOLITIC, ETC.		CLASTIC UNCONSOLIDATED-silt, sand SIZE GRADES (mm.) 1/256 - 1/16, silt; 1/16 - 1/8 very fine sand; 1/8 - 1/4, fine sand; 1/4 - 1/2, medium sand; 1/2 - 1, coarse sand; 1-2 very coarse sand CONSOLIDATED - siltstone, sandstone					CLASTIC UNCONSOLIDATED - gravel (rounded), rubble (angular) CONSOLIDATED - conglomerate (rounded), breccia (angular) SIZE GRADES (mm.) - 2-4, granules; 4-64, pebbles; 64-256 cobbles; > 256 boulders		
COMPOSITION OF MAJOR FRACTION	Composition as Indicated in left column (prefix appropriate names for mixtures)	Clay Minerals or Clay-Size Material	Compositon as Indicated in left column (prefix appropriate names for mixtures)	Chiefly Calcite or Dolomite	Chiefly Quartz			Quartz and > 25% Feldspar	Quartz, Feldspar, Rock Chips, Pelitic Matrix, Angular grains, Tough.	Volcanic Ejecta	CHIEFLY ONE CONSTITUENT Especially quartz, chert, or quartzite. Also shale or limestone. Homogeneous conglomerates and breccias.	SEVERAL CONSTITUENTS Usually including unstable constituents. Mixed conglomerates and breccias.
COMPOSITION OF MINOR FRACTION					> 90% Quartz	Feldspar 10-25%	Rock Chips > 10%					
< 10% Minor Fraction				**LIMESTONE** **DOLOMITE** **ETC.** All varieties in the Calcite-Dolomite horizontal column are possible here.	**QUARTZ SANDSTONE** (Quartzose sandstone)	**FELDSPATHIC SANDSTONE**	**LITHIC SANDSTONE**	**ARKOSE** (Arkosic sandstone) Normally pink, red or light gray	**GRAYWACKE**—normally greenish gray **SUBGRAYWACKE**—low in feldspar, rock chips, or less angular grains. Tendency to chemical cement	**ASH**—unconsolidated fragments under 4 mm. **TUFF**—consolidated ash **VOLCANIC BRECCIA**—angular fragments over 4 mm. **AGGLOMERATE**—large proportion (> 25%) of bombs These rocks are classified on the proportions of vitric, crystal (mineral), or lithic material they contain, for example: "vitric lithic ash," or "crystal vitric tuff." If the mineralogy of the crystal or lithic fragments can be determined, the name of the appropriate volcanic rock can be prefixed as, "rhyolite vitric crystal tuff," or simply, "rhyolite tuff."	Name consists of chief constituent and size grade, for example: QUARTZ PEBBLE CONGLOMERATE CHERT COBBLE CONGLOMERATE LIMESTONE PEBBLE BRECCIA ETC.	Name consists of "mixed" or polycomponent" and size grade, for example: MIXED PEBBLE CONGLOMERATE or MIXED COBBLE CONGLOMERATE Name may include composition as GRAYWACKE-ANDESITE-CHERT PEBBLE CONGLOMERATE
Clay Minerals or Clay-Size Materials	**CLAYSTONE**—massive, blocky structure. **MUDSTONE**—indurated mud. Includes claystone and siltstone. **SHALE**—finely fissile. May include much silt. **CLAY SHALE** (Argillaceous shale—chiefly clay minerals. **ARGILLITE**—highly indurated. Incipiently recrystallized. **BENTONITE**—swells and disaggregates in water.			**ARGILLACEOUS LIMESTONE** **ETC.** All varities in the Calcite-Dolomite horizontal column are possible here.	**ARGILLACEOUS QUARTZ SANDSTONE**	**ARGILLACEOUS FELDSPATHIC SANDSTONE** **LOESS**—fine sand or silt. Massive, porous, coherent	**ARGILLACEOUS LITHIC SANDSTONE**	**ARGILLACEOUS ARKOSE**	**ARGILLACEOUS GRAYWACKE** **ARGILLACEOUS SUBGRAYWACKE**		**ARGILLACEOUS** (rock, grade) **CONGLOMERATE**—uncommon with stable constituent	**ARGILLACEOUS MIXED** (grade) **CONGLOMERATE** **GLACIAL TILL**—chaotic mixture of clay, sand and gravel **TILLITE**—indurated till **FANGLOMERATE**—alluvial fan material
SILICA Opal Chalcedony Quartz	**CHERT**—chalcedony or opal. Bedded, nodular, massive. **DIATOMITE** (Diatomaceous earth)—diatom tests. **RADIOLARITE** (Tripoli, in part)—radiolarion tests. **SILICEOUS SINTER** (Geysenite)—porous geyser deposit. **PORCELLANITE**—orgillaceous or silty chert.	**SILICEOUS SHALE** **SILICEOUS CLAYSTONE** **SILICEOUS MUDSTONE** **ETC.**	**SILICEOUS OOLITE**—> 50% oolitic **OOLITIC CHERT**—< 5% oolitic **DIATOMITE**—diatom tes.s **RADIOLARITE**—radiolarian tests	**SILICEOUS LIMESTONE**—disseminated silica **CHERTY LIMESTONE**—containing chert nodules **ETC.** All varieties in the Calcite-Dolomite horizontal column are possible here.	**ORTHOQUARTZITE** (Sedimentary quartzite) (Siliceous quartz sandstone)	**FELDSPATHIC ORTHOQUARTZITE** (Siliceous feldspathic sandstone)	**LITHIC ORTHOQUARTZITE** (Siliceous lithic sandstone)	**SILICEOUS ARKOSE** (Quartzitic arkose)	**SILICEOUS SUBGRAYWACKE**		**SILICEOUS** (rock, grade) **CONGLOMERATE** Orthoquartzitic [rock, grade] conglomerate)	**SILICEOUS MIXED** (grade) **CONGLOMERATE**
CALCITE OR DOLOMITE	**LIMESTONE**—cheifly calcite, massive. **DOLOMITE** (Dolostone)—chiefly dolomite, massive. **CHALK**—chalky texture **TUFA**—very porous, friable. **TRAVERTINE**—banded, coherent, denser than tufa. **CALICHE**—lime-rich deposit formed near surface.	**CALCAREOUS SHALE** (Limy shale) etc. **MARLSTONE** 25-75% carbonate	**LIMESTONE**—chiefly calcite, crystalline **DOLOMITE** (Dolostone)—chiefly dolomite, crystalline **CLASTIC LIMESTONE** (Calcarenite or calcite sandstone)—clastic **CALCAREOUS OOLITE**—> 50% oolitic; **OOLITIC limestone**—< 50% oolitic. **COQUINA**—shells, little cement **ORGANIC LIMESTONE**—Richly fossiliferous		**CALCAREOUS QUARTZ SANDSTONE**	**CALCAREOUS FELDSPATHIC SANDSTONE**	**CALCAREOUS LITHIC SANDSTONE**	**CALCAREOUS ARKOSE**	**CALCAREOUS SUBGRAYWACKE**		**CALCAREOUS** (rock, grade) **CONGLOMERATE**	**CALCAREOUS MIXED** (grade) **CONGLOMERATE**
IRON MINERALS Chiefly: Limonite Goethite Hematite Siderite Chamosite	**HEMATITE ROCK**—massive hematite. **LIMONITE ROCK**—massive limonite. **BOG IRON ORE**—earthy, impure, limonite. **IRONSTONE** (Clay ironstone)—coherent mixture of iron, silica, clay, and carbonate. **SIDERITE** (Iron carborate)—massive siderite.	**LIMONITIC Or HEMATITIC** (Ferruginous) **SHALE ETC.**	**HERMATITE OOLITE**—> 50% oolitic **LIMONITE OOLITE**—> 50% oolitic **OOLITIC IRON ORE**—< 50% oolitic **SIDERITE** (Iron carbonate)—chiefly siderite, crystalline	**LIMONITIC or HEMATITIC (Ferruginous) LIMESTONE** **ETC.** All varieties in the Calcite-Dolomite horizontal column are possible here.	**LIMONITIC or HEMATITIC (Ferruginous) QUARTZ SANDSTONE**	**LIMONITIC or HEMATITIC (Ferruginous) FELDSPATHIC SANDSTONE**	**LIMONITIC or HEMATITIC (Ferruginous) LITHIC SANDSTONE**	**LIMONITIC or HEMATITIC (Ferruginous) ARKOSE**	**LIMONITE or HEMATITIC (Ferruginous) GRAYWACKE** **LIMONITIC or HEMATITIC (Ferruginous) SUBGRAYWACKE**		**LIMONITIC or HEMATITIC (Ferruginous)** (rock, grade) **CONGLOMERATE**	**LIMONITIC or HEMATITIC (Ferruginous) MIXED** (grade) **CONGLOMERATE**
CARBON Humus-Yields carbonaceous derivatives Sapropel-Yields bituminous derivatives	**COAL** **BITUMINOUS**—Hackly fracture. **ANTHRACITE**—conchoidal fracture. **ASPHALT**—asphatic. **GILSONITE**—black, high luster, amorphous.	**CARBONACEOUS SHALE, ETC.**—carbonized remains. **BITUMINOUS SHALE** (Oil shale) **ETC.**—sapropelic	**PEAT**—dark semi-carbonized plant remains **LIGNITE**—brown-black well-carbonized plant remains	**CARBONACEOUS LIMESTONE** **BITUMINOUS LIMESTONE** **ETC.** All varieties in the Calcite-Dolomite horizontal column are possible here.	**CARBONACEOUS QUARTZ SANDSTONE** **BITUMINOUS QUARTZ SANDSTONE**	**CARBONACEOUS FELDSPATIC SANDSTONE** **BITUMINOUS FELDSPATHIC SANDSTONE**	**CARBONACEOUS LITHIC SANDSTONE** **BITUMINOUS LITHIC SANDSTONE**	**CARBONACEOUS ARKOSE** **BITUMINOUS ARKOSE**	**CARBONACEOUS GRAYWACKE ETC.** **CARBONACEOUS SUBGRAYWACKE ETC.**		**CARBONACEOUS** (rock, grade) **CONGLOMERATE** **BITUMINUS** (rock, grade) **CONGLOMERATE**	**CARBONACEOUS MIXED** (grade) **CONGLOMERATE** **BITUMINOUS MIXED** (grade) **CONGLOMERATE**
MISCELLANEOUS Phosphate (Collophane) Evaporites Halite and Sylvite Anhydrite Gypsum	**PHOSPHORITE**—phosphate rock. **ROCK SALT**—massive halite or sylvite. **ROCK ANHYDRITE**—massive anhydrite. **ROCK GYPSUM**—massive gypsum.	**PHOSPHATIC SHALE, ETC.**	**PHOSPHATIC OOLITE**—> 50% oolitic **ROCK SALT**—crystalline **ROCK ANHYDRITE**—crystalline **ROCK GYPSUM**—crystalline **GYPSUM SAND**—clastic	**PHOSPHATIC LIMESTONE** **ETC.** All varieties in the Calcite-Dolomite horizontal column are possible here.	**PHOSPHATIC QUARTZ SANDSTONE ETC.**	**PHOSPHATIC FELDSPATHIC SANDSTONE ETC.**	**PHOSPHATIC LITHIC SANDSTONE ETC.**	**PHOSPHATIC ARKOSE ETC.**	**PHOSPHATIC SUBGRAYWACKE ETC.**		**PHOSPHATIC** (rock, grade) **CONGLOMERATE**	**PHOSPHATIC MIXED** (grade) **CONGLOMERATE**

The names in the above chart are root names and should be preceded by appropriate terms for any significant feature of the rock. The proper order is color, structure, grain size (sandstones only), minor constituents, cement, and root name. Structure includes, for example, "thin-bedded," "massive," "cross-bedded," thinly laminated," etc. The size grade for conglomerates should immediately precede "conglomerate." Some common nonmineral minor constituent terms are "tuffaceous," "cherty," "fossiliferous," "crinoidal," "coralline," "clayey (argillaceous)," "silty," "shaly," "sandy (arenaceous)," and "conglomeratic." Minor mineralogy should follow the nonmineral composition and should be restricted to one conspicuous mineral not implied in the root name. It should be applied in adjective form as "micaceous," "chloritic," "glauconitic," and pyritic." The most common cement terms are given in the chart with the root names. Some typical rock names are "black thin-bedded micacous shale," "gray massive, medium-grained glauconitic quartz sandstone," "tan siliceous quartz pebble conglomerate," and "white vuggy foraminiferal limestone."

Graywacke currently has two meanings. To some, it denotes a feldspar-quartz sandstone with more than 20 (or 15) percent pelitic matrix. To many others, it has retained its original meaning; that is a very hard, firm sandstone without porosity or chemical cement. In addition, these "true" graywackes typically have extremely angular grains, a pelitic matrix, and a dark color.

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CLASSIFICATION OF METAMORPHIC ROCKS
By Russell B. Travis

COLOR	CHIEF MINERALS	CHARACTERIZING ACCESSORY MINERALS	NONDIRECTIONAL STRUCTURE Massive or Granulose		DIRECTIONAL STRUCTURE (Lineate or Foliate)					
			Contact Metamorphism*		Mechanical Metamorphism	Regional Metamorphism				Plutonic Metamorphism
			Fine Grained (Aphanitic)	Medium or Coarse Grained (Phaneritic)	Cataclastic	Slaty	Phyllitic	Schistose	Gneissose	Migmatitic
LIGHT	QUARTZ FELDSPAR CALCITE DOLOMITE TALC MUSCOVITE SERICITE		METAQUARTZITE MARBLE BRUCITE MARBLE SOAPSTONE—chiefly talc HORNFELS—any metamorphic rock with nondirectional structure	METAQUARTZITE MARBLE BRUCITE MARBLE TREMOLITE MARBLE WOLLASTONITE MARBLE TREMOLITE HORNFELS WOLLASTONITE HORNFELS CALC-SILICATE HORNFELS—chiefly calc-silicate minerals	These rocks are formed by crushing and shearing with only minor recrystallization. If there are no conspicuous directional features, the rock is called "crush breccia" if coarse grained, and "cataclasite" if fine grained. Most of them, however, are foliate. MYLONITE—finely ground, foliate FLASER GRANITE, FLASER DIORITE, FLASER CONGLOMERATE, ETC.—flaser structure AUGEN GNEISS—augen structure ULTRAMYLONITE—partially fused mylonite Rocks with only minor deformation may be called "schistose," for example "schistose sandstone," "schistose rhyolite," etc. but these are not properly metamorphic rocks.		PHYLLITE is intermediate between slate and schist. It differs from slate in that crystallization of micaceous minerals imparts a sheen to the rock; it differs from schist in that grains are too small for megascopic identification. PHYLLONITE—a phyllite owing its fine grain to mylonitization.	QUARTZ-MICA SCHIST TALC SCHIST SILLIMANITE SCHIST ALBITE-MICA SCHIST QUARTZ-SERICITE SCHIST KYANITE SCHIST CALCITE SCHIST (Schistose marble)	RHYOLITE GNEISS QUARTZ PORPHYRY GNEISS QUARTZITE GNEISS SILLIMANITE GNEISS GRANULITE—banding due to elongated quartz or feldspar grains	These rocks have a gneissose, streaked, or irregular structure produced by intimate mixing of metamorphic and magmatic materials. When they can be recognized as "mixed rock," they are called migmatite or migmatite gneiss. They may originate by injection (injection migmatite, injection gneiss, or lit-par-lit gneiss), or by differential fusion. Many so-called migmatites probably originate by partial granitization or by metamorphic differentiation. But at great depth these processes apparently do not differ substantially from the igneous processes forming migmatite, so the products are usually indistinguishable. Migmatites are named by prefixing the rock name of the granitic material to the appropriate root as "granite migmatite," "monzonite injection migmatite," etc.
INTERMEDIATE (Includes Red or Brown)	ABOUT EQUAL PROPORTIONS OF LIGHT-COLORED AND DARK-COLORED MINERALS	Muscovite Sericite Sillimanite Kyanite Cordierite Tremolite Wollastonite Albite Andalusite Garnet Phlogopite Diopside Enstatite Staurolite Glaucophane Anthophyllite Pyrophyllite Chloritoid Actinolite Tourmaline Epidote Chiastolite Olivine Serpentine Chlorite Biotite Graphite Chondrodite Scapolite	METAQUARTZITE MARBLE SKARN—pyroxene-garnet-carbonate hornfels SOAPSTONE—chiefly talc HORNFELS—any metamorphic rock with nondirectional structure SERPENTINE*	METAQUARTZITE MARBLE DIOPSIDE MARBLE CHONDRODITE MARBLE ANDALUSITE HORNFELS SKARN-pyroxene-garnet-carbonate hornfels GARNET HORNFELS KYANITE HORNFELS ANTHOPHYLLITE HORNFELS CALC-SILICATE HORNFELS SERPENTINE* CORDIERITE-ANTHOPHYLLITE HORNFELS		Most slates are dark colored		MICA SCHIST CHIASTOLITE SCHIST ANDALUSITE SCHIST STAUROLITE SCHIST KYANITE SCHIST PYROPHYLLITE SCHIST GARNET-MICA SCHIST SERPENTINE* TOURMALINE-MICA SCHIST ANTHOPHYLLITE SCHIST STAUROLITE-KYANITE SCHIST SILLIMANITE-GARNET SCHIST GRAPHITE SCHIST CALCITE SCHIST (Schistose marble) SCHISTOSE QUARTZITE	GRANITE GNEISS SYENITE GNEISS MONZONITE GNEISS GRANODIORITE GNEISS ANORTHOSITE GNEISS TRACHYTE GNEISS CONGLOMERATE GNEISS ARKOSE GNEISS SANDSTONE GNEISS AUGEN GNEISS—augen structure BIOTITE GNEISS STAUROLITE GNEISS PLAGIOCLASE GNEISS GARNET GNEISS MUSCOVITE-BIOTITE-QUARTZ GNEISS KYANITE GNEISS GRANULITE—banding due to enlongated quartz or feldspar grains	
DARK (Includes Green)	QUARTZ CALCITE DOLOMITE FELDSPAR CHLORITE HORNBLENDE SERPENTINE BIOTITE PYROXENE ACTINOLITE EPIDOTE OLIVINE MAGNETITE		METAQUARTZITE MARBLE SKARN—pyroxene-garnet-carbonate hornfels GRAPHITE MARBLE CHLORITE MARBLE SERPENTINE MARBLE (Ophicalcite) HORNFELS—any metamorphic rock with nondirectional structure SERPENTINE*	METAQUARTZITE MARBLE GRAPHITE MARBLE CHLORITE MARBLE OLIVINE MARBLE SKARN—pyroxene-garnet-carbonate hornfels ACTINOLITE MARBLE ACTINOLITE-EPIDOTE HORNFELS ACTINOLITE HORNFELS PYROXENE HORNFELS EPIDOTE HORNFELS TOURMALINE HORNFELS ANDALUSITE-BIOTITE HORNFELS SERPENTINE* ECLOGITE—pyrope-amphacite hornfels MAGNETITE ROCK CORDIERITE HORNFELS AMPHIBOLITE—chiefly hornblende and or plagioclase		SILTY SLATE GREEN SLATE BLACK SLATE SPOTTED SLATE ANDALUSITE SPOTTED SLATE CHIASTOLITE SPOTTED SLATE BIOTITE SPOTTED SLATE CARBONACEOUS SLATE CALCAREOUS SLATE		GREENSCHIST CHLORITE SCHIST CHLORITOID SCHIST GLAUCOPHANE SCHIST AMPHIBOLITE (HORNBLENDE SCHIST) ACTINOLITE SCHIST GRAPHITE SCHIST PYROXENE SCHIST EPIDOTE-CHLORITE SCHIST HORNBLENDE-BIOTITE SCHIST BIOTITE-CHLORITE SCHIST SERPENTINE* TOURMALINE SCHIST EPIDOTE AMPHIBOLITE GARNET-PYROXENE AMPHIBOLITE GARNET-CHLORITE SCHIST	QUARTZ DIORITE GNEISS DIORITE GNEISS GABBRO GNEISS PERIDOTITE GNEISS DIABASE GNEISS PYROXENE GNEISS GRAYWACKE GNEISS EPIDOTE GNEISS GARNET-BIOTITE GNEISS SKARN GNEISS AMPHIBOLITE GNEISS	

As can be noted from the chart, naming a metamorphic rock consists chiefly of prefixing the structural term with mineral names or an appropriate rock name. The rock name indicates either the original rock, if recognizable, or the new mineral composition. The prefix "meta," as "metagabbro," "metasandstone," "metatuff," etc. is applied to rocks that have undergone considerable recrystallization but have largely retained their original fabric. Most of the minerals listed as accessories are genetically important and if present should be included in the rock name regardless of their quantity.

*SERPENTINE is a product of hydrothermal alteration which some authorities consider to be an igneous process and others a metamorphic process. For this reason, serpentine appears both on this chart and on the igneous rock chart.

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Conversion Factors for Surface Area,
Volumes, Mass, and Flow Rates

LENGTH

1 Statute Mile (mi)	=	5,280	ft	1 Rod (rd)	=	5.5	yd
		1,760	yd			16.5	ft
		1.6094	km				
		8	fg	1 Chain (ch)	=	22	yd
		80	ch			66	ft
		320	rd			4	rd
						100	lk
1 Yard (yd)	=	3	ft	1 Link (lk)	=	7.92	in
		36	in			0.2012	m
		0.91	m			20.12	cm
		91	cm				
				1 Span	=	9	in
1 Foot (ft)	=	12	in				
		30.48	cm	1 Hand	=	4	in
		0.3048	m				
				1 Vara (Mexico)	=	32.99	in
1 Inch (in)	=	0.0833	ft			83.79	cm
		2.54	cm				
		25.4	mm	(Texas)	=	33.33	in
						84.66	cm
1 Kilometer (km)	=	0.625	mi				
		1,091	yd	(AZ & NM)	=	33.00	in
						83.22	cm
1 Meter (m)	=	39.37	in				
1 Furlong (fg)	=	0.125	mi				
		220	yd				
		660	ft				
		10	ch				

AREA

1 Township (twp)	=	36	sq mi	1 Hectare (ha)	=	2.471	ac
1 Section (sec)	=	1	sq mi	1 square chain	=	16	sq rd
		640	ac			484	sq yd
		259	ha			4,356	sq ft
		2.59	sqkm			404.67	sq m
		6,400	sq ch				
1 Acre (ac)	=	43,560	sq ft	1 lode claim	=	20.661	ac
		4,840	sq yd			8.36	ha
		208.7	ft sq			3,305.78	sqrd
		0.405	ha			206.61	sqch
		4,047	sq m				
		10	sq ch	1 Placer claim	=	20	ac
						3,200	sq rd
1 square yard	=	9	sq ft			200	sq ch
		0.84	sq m				
1 square foot	=	144	sq in	1 Mill Site	=	5	ac
		0.093	sq m			2.02	ha
		929	sq cm			800	sq rd

Conversion Factors for Surface Area,
Volumes, Mass, and Flow Rates

COMMERCIAL or AVOIRDUPOIS (avdp)

1 Short ton (st)	=	2,000	lb
1 Long ton (lt)	=	2,240	lb
		1.02	mt
		1.12	st
1 Metric ton (mt)	=	2,204.6	lb
1 Shipping ton	=	40	cu ft
1 Register ton	=	100	cu ft
1 Pound (lb) avdp	=	16	oz
		453.6	g
		14.58	oz tr
		7,000	gr

1 Ounce (oz)	=	28.35	g
		437.5	gr
1 Kilogram (kg)	=	2.205	lb
		35.274	oz
1 Gram (g)	=	0.035	oz
		15.432	gr
1 Part/million (ppm)	=	0.035	oz
		1	gr/mt
1 oz/st	=	31.25	mg/kg
1 g/st	=	1.10	mg/kg

TROY WEIGHT (for Precious Metals)

1 Troy pound (tr lb)	=	12	tr oz
		5,760	gr
		240	dwt
		0.823	lb avdp
1 Troy ounce	=	31.104	g
		20	dwt
		480	gr
1 Pennyweight (dwt)	=	1.555	g
		24	gr
1 Cu in of fine placer gold	=	10.168	tr oz
		316.269	g
		4,880.64	gr

1 Troy oz/st	=	34.286	ppm
		34.286	g/mt
1 ppm	=	1	g/mt
		0.029	troz/mt
1 Carat	=	3.086	gr
1 Assay ton	=	29.167	g
		1 part in 250,000	

Conversion Factors for Surface Area,
Volumes, Mass, and Flow Rates

VOLUME

1 Cubic yard (cu yd) =	27 cu ft 0.765 cu m 201.95 gal 764.42 l	1 Acre-foot (ac-ft) =	43,560 cu ft 1,233 cu m 12 ac in
1 Cubic foot (cu ft) =	1,728 cu in 0.028 cu m 7.48 gal 28.31 l	1 U S gallon (gal) =	128 fl oz 231 cu in 0.134 cuin
1 Cubic inch (cu in) =	16.39 cu cm 0.016 l	1 Fluid ounce (fl oz) =	1.805 cuin 29.57 cucm
1 Cubic meter (cu m) =	1.31 cu yd 35.32 cu ft	1 Barrel Oil (bbl) =	42 gal 5.62 cuft 0.16 cum 158.97 l 9702 cu in
1 Cubic centimeter (ccm) =	0.61 cu in		
1 Liter (l) =	61 cu in 0.04 cu ft 0.264 gal	1 Bushel =	1.24 cuft 9.31 gal 35.24 l

FLOW RATES

1 Cubic foot/sec (cfs) =	7.48 gal/s 448.83 gpm 1,699.3 l/s 0.992 ac in/hr 1.983 ac ft/hr	1 miners inch (AZ,CA,MT,OR) =	710.4 ccm/s 11.3 gpm 0.7 l/s 0.2 acin/hr 0.025cfs
1 Gallon/minute (gpm) =	0.002 cfs 0.063 l/s 63.146 ccm/s 1,440 gal/day	(CO) =	738.12 ccm/s 11.69 gpm 0.738 l/s 0.026 acin/hr 0.026cfs
1 cubic meter/sec (cu m/s) =	35.31 cfs 264.12 gpm	(ID,KS,NB,NV,NM,ND, SD,UT) =	568.3 ccm/s 9.0 gpm 0.5681/s 0.020 acin/hr 0.020 cfs
1 Liter/sec (l/s) =	0.035 cfs 15.85 gpm 543.48 bbl/day		

Miscellaneous Units

1 barrel liquid =	31.5 gal	1 British hundred weight (cwt) =	112 lbs 50.8 kg
1 Hogshead =	2 bbl		
1 Pipe or butt =	4 bbl	1 Degree C =	1.8 F
1 Gallon of water =	8.33 lb @ 62F	1 cu ft of water =	62.5 lbs @ 62F
1 Short ton of water =	240 gal 908 l	1 Flask of Mercury =	76 lbs

Remove?

Trigon

Degree	Sine	Tangent	Cosine	Cotangent	Degree
0	0.0000	0.0000	1.0000	INFINITY	90
1	0.0175	0.0175	0.9998	57.2900	89
2	0.0349	0.0349	0.9994	28.6363	88
3	0.0523	0.524	0.9986	19.0811	87
4	0.0698	0.0699	0.9976	14.3007	86
5	0.0872	0.0875	0.9962	11.4301	85
6	0.1045	0.1051	0.9945	9.5144	84
7	0.1219	0.1228	0.9925	8.1443	83
8	0.1392	0.1405	0.9903	7.1154	82
9	0.1564	0.1584	0.9877	6.3138	81
10	0.1737	0.1763	0.9848	5.6713	80
11	0.1908	0.1944	0.9816	5.1446	79
12	0.2079	0.2126	0.9781	4.7046	78
13	0.2250	0.2309	0.9744	4.3315	77
14	0.2419	0.2493	0.9703	4.0108	76
15	0.2588	0.2679	0.9659	3.7321	75
16	0.2756	0.2867	0.9613	3.4874	74
17	0.2924	0.3057	0.9563	3.2709	73
18	0.3090	0.3249	0.9511	3.0777	72
19	0.3256	0.3443	0.9455	2.9042	71
20	0.3420	0.3640	0.9397	2.7475	70
21	0.3584	0.3839	0.9336	2.6051	69
22	0.3746	0.4040	0.9272	2.4751	68
23	0.3907	0.4245	0.9205	2.3559	67
24	0.4067	0.4452	0.9135	2.2460	66
25	0.4226	0.4663	0.9063	2.1445	65
26	0.4384	0.4877	0.8988	2.0503	64
27	0.4540	0.5095	0.8910	1.9626	63
28	0.4695	0.5317	0.8830	1.8807	62
29	0.4848	0.5543	0.8746	1.8041	61
30	0.5000	0.5774	0.8660	1.7321	60
31	0.5150	0.6009	0.8572	1.6643	59
32	0.5299	0.6249	0.8480	1.6003	58
33	0.5446	0.6494	0.8387	1.5399	57
34	0.5592	0.6745	0.8290	1.4826	56
35	0.5736	0.7002	0.8192	1.4281	55
36	0.5878	0.7265	0.8090	1.3764	54
37	0.6018	0.7536	0.7986	1.3270	53
38	0.6157	0.7813	0.7880	1.2799	52
39	0.6293	0.8098	0.7771	1.2349	51
40	0.6428	0.8391	0.7660	1.1918	50
41	0.6560	0.8693	0.7547	1.1504	49
42	0.6691	0.9004	0.7431	1.1106	48
43	0.6820	0.9325	0.7314	1.0724	47
44	0.6947	0.9657	0.7193	1.0355	46
45	0.7071	1.0000	0.7071	1.0000	45
Degree	Cosine	Cotangent	Sine	Tangent	Degree

Solving Triangles

Let A = angle BAC = arc BF, and let the radius $AF = AB = AH = 1$. We then have

$\sin A = BC$
$\cos A = AC$
$\tan A = DF$
$\cot A = HG$
$\sec A = AD$
$\operatorname{cosec} A = AG$
$\operatorname{versin} A = CF = BE$
$\operatorname{covers} A = BK = HL$
$\operatorname{exsec} A = BD$
$\operatorname{coexsec} A = FG$
$\operatorname{chord} A = BF$
$\operatorname{chord} 2A = BI = 2BC$

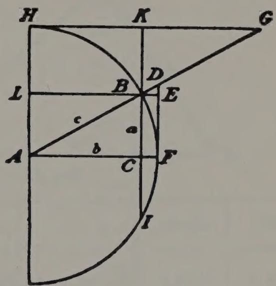


Fig 1.

In the right-angled triangle ABC Let $AB = c$, $AC = b$, and $BC = a$. We then have:

1. $\sin A = \dfrac{a}{c} = \cos B$
2. $\cos A = \dfrac{b}{c} = \sin B$
3. $\tan A = \dfrac{a}{b} = \cot B$
4. $\cot A = \dfrac{b}{a} = \tan B$
5. $\sec A = \dfrac{c}{b} = \operatorname{cosec} B$
6. $\operatorname{cosec} A = \dfrac{c}{a} = \sec B$
7. $\operatorname{vers} A = \dfrac{c-b}{c} = \operatorname{covers} B$
8. $\operatorname{exsec} A = \dfrac{c-b}{b} = \operatorname{coexsec} B$
9. $\operatorname{covers} A = \dfrac{c-a}{c} = \operatorname{versin} B$
10. $\operatorname{coexsec} A = \dfrac{c-a}{a} = \operatorname{exsec} B$
11. $a = c \sin A = b \tan A$
12. $b = c \cos A = a \cot A$
13. $c = \dfrac{a}{\sin A} = \dfrac{b}{\cos A}$
14. $a = c \cos B = b \cot B$
15. $b = c \sin B = a \tan B$
16. $c = \dfrac{a}{\cos B} = \dfrac{b}{\sin B}$
17. $a = \sqrt{(c+b)(c-b)}$
18. $b = \sqrt{(c+a)(c-a)}$
19. $c = \sqrt{a^2+b^2}$
20. $C = 90° = A+B$
21. $\text{area} = \dfrac{ab}{2}$

Solving Triangles

SOLUTION OF OBLIQUE TRIANGLES.

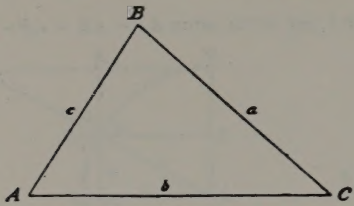
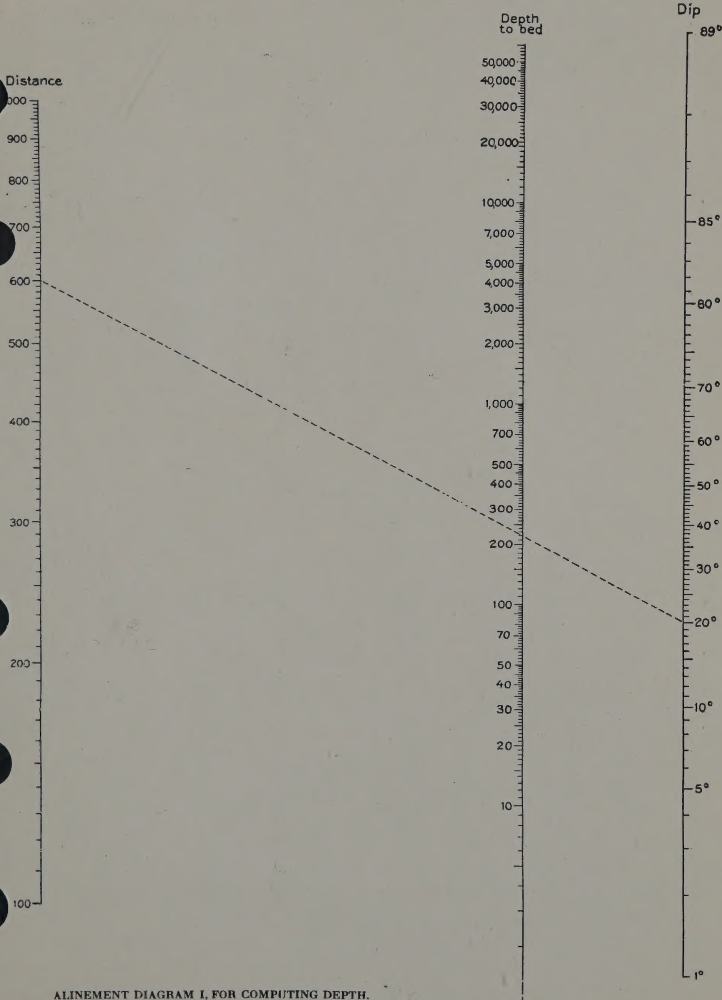


FIG. 2.

GIVEN.	SOUGHT.	FORMULA.
A, B, a	C, b, c	$C=180^\circ-(A+B)$, $\quad b=\frac{a}{\sin A}\cdot\sin B$,
		$c=\frac{a}{\sin A}\sin(A+B)$
A, a, b	B, C, c	$\sin B=\frac{\sin A}{a}\cdot b$, $\quad C=180^\circ-(A+B)$,
		$c=\frac{a}{\sin A}\cdot\sin C$.
C, a, b	$\frac{1}{2}(A+B)$	$\frac{1}{2}(A+B)=90^\circ-\frac{1}{2}C$
	$\frac{1}{2}(A-B)$	$\tan\frac{1}{2}(A-B)=\frac{a-b}{a+b}\tan\frac{1}{2}(A+B)$
	A, B	$A=\frac{1}{2}(A+B)+\frac{1}{2}(A-B)$, $B=\frac{1}{2}(A+B)-\frac{1}{2}(A-B)$
	c	$c=(a+b)\frac{\cos\frac{1}{2}(A+B)}{\cos\frac{1}{2}(A-B)}=\sqrt{a^2+b^2-2ab\cos C}$
	area	$\text{area}=\frac{1}{2}ab\sin C$.
a, b, c	A	Let $s=\frac{1}{2}(a+b+c)$; $\sin\frac{1}{2}A=\sqrt{\frac{(s-b)(s-c)}{bc}}$
		$\cos\frac{1}{2}A=\sqrt{\frac{s(s-a)}{bc}}$; $\tan\frac{1}{2}A=\sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$
		$\sin A=\frac{2\sqrt{s(s-a)(s-b)(s-c)}}{bc}$;
		$\cos A=\frac{b^2+c^2-a^2}{2bc}$
	area	$\text{area}=\sqrt{s(s-a)(s-b)(s-c)}$
A, B, C, a	area	$\text{area}=\frac{a^2\sin B\cdot\sin C}{2\sin A}$

Nomograms for Stratigraphic Conversions

U. S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 120 PLATE XIV

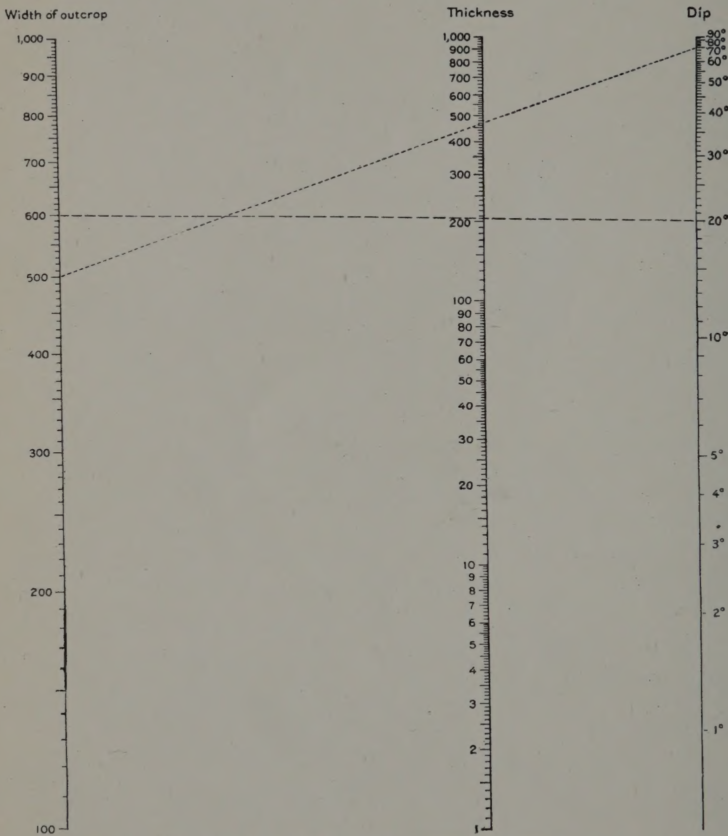


ALINEMENT DIAGRAM I, FOR COMPUTING DEPTH.

Nomograms for Stratagraphic Conversions

U. S. GEOLOGICAL SURVEY

PROFESSIONAL PAPER 120 PLATE XV

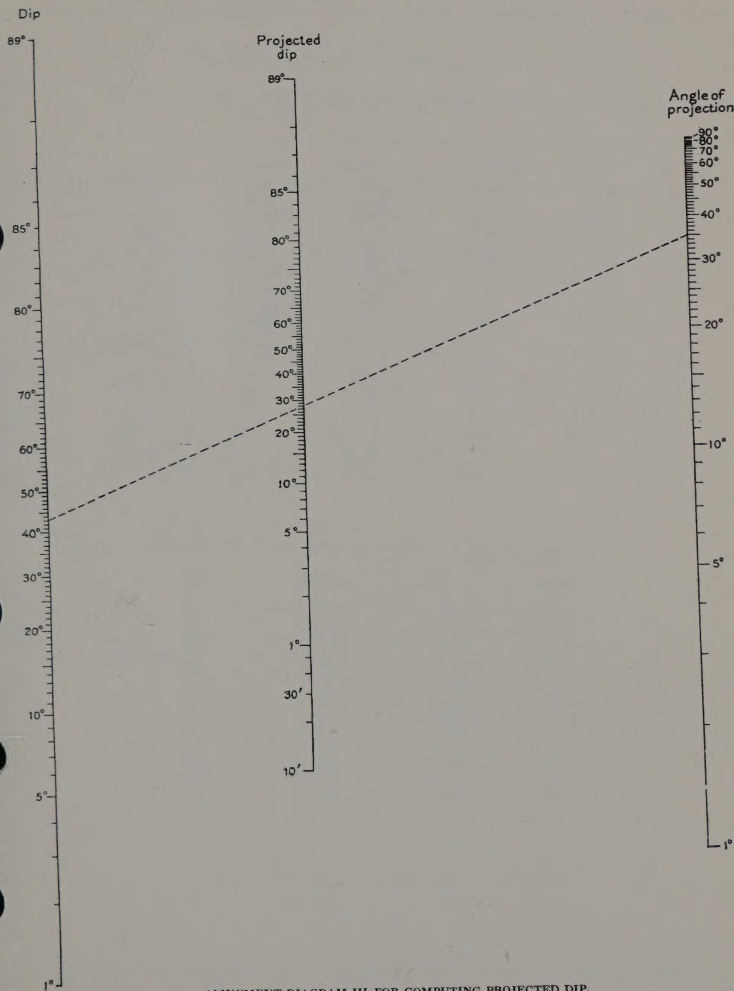


ALINEMENT DIAGRAM II, FOR COMPUTING THICKNESS.

Nomographs for Stratagraphic Conversions

U. S. GEOLOGICAL SURVEY

PROFESSIONAL PAPER 120 PLATE XVI



ALINEMENT DIAGRAM III, FOR COMPUTING PROJECTED DIP.

Assay Conversions

Parts per Million to Percent and Troy Ounces per Ton

Parts per million to percent to ounces per ton			Ounces per ton to percent to parts per million		
Ppm	Percent	Oz per ton	Oz per ton	Percent	Ppm
0.01	0.000001	0.0003	0.01	0.00003	0.3
0.02	0.000002	0.0006	0.02	0.00007	0.7
0.05	0.000005	0.0015	0.05	0.00017	1.7
0.10	0.00001	0.003	0.10	0.00034	3.4
0.20	0.00002	0.006	0.20	0.00069	6.9
0.30	0.00003	0.009	0.30	0.00103	10.3
0.40	0.00004	0.012	0.40	0.0137	13.7
0.50	0.00005	0.015	0.50	0.00171	17.1
0.60	0.00006	0.017	0.60	0.00206	20.6
0.70	0.00007	0.020	0.70	0.00240	24.4
0.80	0.00008	0.023	0.80	0.00274	27.4
0.90	0.00009	0.026	0.90	0.00309	30.9
1.0	0.0001	0.029	1.0	0.00343	34.3
10.0	0.001	0.292	10.0	0.03429	342.9
20.0	0.002	0.583	20.0	0.06857	685.7
50.0	0.005	1.458	50.0	0.17143	1,714.0
100.0	0.01	2.917	100.0	0.34286	3,429.0
500.0	0.05	14.583	500.0	1.71	17,143.0
1,000.0	0.10	29.167	1,000.0	3.43	34,286.0
10,000.0	1.00	291.667	10,000.0	34.29	342,857.0

Parts per Billion, by Weight, to Troy Ounces per short ton.

ppb	oz/ton	ppb	oz/ton
5	0.00015	600	0.0175
10	0.00029	700	0.0204
20	0.00058	800	0.0233
30	0.00088	900	0.0262
40	0.00117	1,000	0.029
50	0.00146	2,000	0.058
60	0.00175	3,000	0.087
70	0.00204	4,000	0.116
80	0.00233	5,000	0.146
90	0.00262	6,000	0.175
100	0.0029	7,000	0.204
200	0.0058	8,000	0.233
300	0.0088	9,000	0.262
400	0.0116	10,000	0.292
500	0.0146		

Grams Per Metric Ton (Tonne) to Troy Ounces Per Short Ton

Gram/ tonne	oz./ ton	Gram/ tonne	oz./ ton	Gram/ tonne	oz. ton	Gram/ tonne	oz./ ton	Gram/ tonne	oz./ ton
0.1	0.003	4.7	0.137	9.3	0.272	13.9	0.406	18.5	0.540
0.2	0.006	4.8	0.140	9.4	0.274	14.0	0.409	18.6	0.543
0.3	0.009	4.9	0.143	9.5	0.277	14.1	0.412	18.7	0.546
0.4	0.012	5.0	0.146	9.6	0.28	14.2	0.415	18.8	0.549
0.5	0.015	5.1	0.149	9.7	0.283	14.3	0.418	18.9	0.552
0.6	0.017	5.2	0.152	9.8	0.286	14.4	0.42	19.0	0.555
0.7	0.02	5.3	0.155	9.9	0.289	14.5	0.423	19.1	0.558
0.8	0.023	5.4	0.158	10.0	0.292	14.6	0.426	19.2	0.561
0.9	0.026	5.5	0.161	10.1	0.295	14.7	0.429	19.3	0.564
1.0	0.029	5.6	0.164	10.2	0.298	14.8	0.432	19.4	0.566
1.1	0.032	5.7	0.166	10.3	0.301	14.9	0.435	19.5	0.569
1.2	0.035	5.8	0.169	10.4	0.304	15.0	0.438	19.6	0.572
1.3	0.038	5.9	0.172	10.5	0.307	15.1	0.441	19.7	0.575
1.4	0.041	6.0	0.175	10.6	0.310	15.2	0.444	19.8	0.578
1.5	0.044	6.1	0.178	10.7	0.312	15.3	0.447	19.9	0.581
1.6	0.047	6.2	0.181	10.8	0.315	15.4	0.45	20.0	0.584
1.7	0.05	6.3	0.184	10.9	0.318	15.5	0.453	22.0	0.642
1.8	0.053	6.4	0.187	11.0	0.321	15.6	0.456	23.0	0.672
1.9	0.055	6.5	0.190	11.1	0.324	15.7	0.458	24.0	0.701
2.0	0.058	6.6	0.193	11.2	0.327	15.8	0.461	25.0	0.73
2.1	0.061	6.7	0.196	11.3	0.33	15.9	0.464	26.0	0.759
2.2	0.064	6.8	0.199	11.4	0.333	16.0	0.467	27.0	0.788
2.3	0.067	6.9	0.201	11.5	0.336	16.1	0.47	28.0	0.818
2.4	0.07	7.0	0.204	11.6	0.339	16.2	0.473	29.0	0.847
2.5	0.073	7.1	0.207	11.7	0.342	16.3	0.476	30.0	0.876
2.6	0.076	7.2	0.210	11.8	0.345	16.4	0.479	31.0	0.905
2.7	0.079	7.3	0.213	11.9	0.347	16.5	0.482	32.0	0.934
2.8	0.082	7.4	0.216	12.0	0.350	16.6	0.485	33.0	0.964
2.9	0.085	7.5	0.219	12.1	0.353	16.7	0.488	34.0	0.993
3.0	0.088	7.6	0.222	12.2	0.356	16.8	0.491	35.0	1.022
3.1	0.091	7.7	0.225	12.3	0.359	16.9	0.493	36.0	1.051
3.2	0.093	7.8	0.228	12.4	0.362	17.0	0.496	37.0	1.08
3.3	0.096	7.9	0.231	12.5	0.365	17.1	0.499	38.0	1.11
3.4	0.099	8.0	0.234	12.6	0.368	17.2	0.502	39.0	1.139
3.5	0.102	8.1	0.237	12.7	0.371	17.3	0.505	40.0	1.168
3.6	0.105	8.2	0.239	12.8	0.374	17.4	0.508	45.0	1.314
3.7	0.108	8.3	0.242	12.9	0.377	17.5	0.511	50.0	1.46
3.8	0.111	8.4	0.245	13.0	0.38	17.6	0.514	55.0	1.606
3.9	0.114	8.5	0.248	13.1	0.383	17.7	0.517	60.0	1.752
4.0	0.117	8.6	0.251	13.2	0.385	17.8	0.52	65.0	1.898
4.1	0.12	8.7	0.254	13.3	0.388	17.9	0.523	70.0	2.044
4.2	0.123	8.8	0.257	13.4	0.391	18.0	0.526	75.0	2.19
4.3	0.126	8.9	0.26	13.5	0.394	18.1	0.529	100.0	2.92
4.4	0.128	9.0	0.263	13.6	0.397	18.2	0.531		
4.5	0.131	9.1	0.266	13.7	0.4	18.3	0.534		
4.6	0.134	9.2	0.269	13.8	0.403	18.4	0.537		

Accuracy of Various Analytical Techniques

The following tables were provided by the U.S. Bureau of Mines. In the following tables, these abbreviations are employed.

ICP = Induction Coupled Plasma Arc
OES = Optical Emission Spectrographic Analysis
FA = Fire Assay
AA = Atomic Absorption Spectrophotometry Analysis

Lower Detection Limits for ICP and OES.

Ppm in Samples	ug/ml	Elements
0.01-0.1	0.0001-.001	Be, Mn, Sr
0.1- 1.0	0.001- .01	Ba, Cd, Co, Fe, Li, Ti, Y
1-10	0.001- .01	Ag, Au, B, Cr, Cu, Hg, La, Mg, No, Nb, Ni, Pb, Pd, Pt, Sn, Th, V, Zn, Zr
10-50	0.1-0.5	Al, As, Bi, Ca, Ga, K, Na, P, Sb, Te, U, W
100-1000	1-10	Se, Si

Lower Detection Limits in Troy Oz/St.

Element	FA	FA/ICP	FA/AA
Au	0.005	0.0002	0.0009
Ag	0.05	0.002	0.0009
Pt	--	0.001	0.005
Pd	--	0.001	0.001

Minimum Sample Weight for Gold Assays

Sample size, in grams, required for 90 percent accuracy:

Grade Oz/Ton	70 mesh (0.212 mm)	100 mesh (0.150 mm)	140 mesh (0.106 mm)	200 mesh (0.075 mm)
0.5	36.5	13.2	4.8	1.6
0.1	207.0	74.0	26.0	9.3
0.05	409.0	146.0	53.0	18.0
0.01	2047.0	731.0	267.0	91.0
0.005	4096.0	1463.0	533.0	183.0

NB: This table assumes that the gold particles are equal in size to the size of the mesh. The normal size of sample assayed in the lab is one assay ton, 29.167 grams. This table is an estimate only and the values are not absolute. For fine gold ores (Carlin Type) this table over estimates the amount needed for assay.

Accuracy of Various Analytical Techniques

Lower Detection limits for Atomic Absorption Spectrophotometry.

ELEMENT	DETECTION Limit ug/ml	SOLID 1g/100ml (ppm)	SANDBERG 25:1	$PbCl_2$ 200:1
Ag	0.05	5	1	10
Al	1	1,250*	25	
As	1	100	25	
Au	0.1		2	
Ba	2	200		
Be	0.03	15	1	
Bi	0.6	100	15	
Ca	1.0#	100#	8#	60
Cd	0.03	300	0.7	6
Co	0.1	10	2	20
Cr	0.1	50!	3	
Cs	0.1			
Cu	0.05	5	1	10
Eu	3	300		
Fe	0.1	10	4	20
Ga	1	100		
Hf	20	2,000		
Hg	10			
In	0.2	1@		
K	0.1	10	2	20
Li	0.1	10	2	20
Mg	0.03	3	0.7	6
Mn	0.05	5	1	10
Mo	0.3	50	8	200
Na	0.1	10	2	20
Nd	30	3,000		
Ni	0.1	10	2	20
Pb	0.3	30	8	
Pd	0.2+			
Pr	10	1,000		
Pt	2+			
Rb	0.1			
Re	0.05	5		
Rh	0.1			
Sb	1	100	25	600
Se	1	100		
Si	10	12,500*		
Sm	1	100		
Sn	2	300	50	600
Sr	0.1	10		
Ta	50	5,000		
Te	1	100		
Ti	2	625*		
Tl	0.2	1@		
V	2	200	50	
W	25	2,500		
Zn	0.05	5	1	10

! = Fusion
@ = Solvent Extraction
* = $LiBO_2$
# = Easily Contaminated
+ = 2X Dilution in Lanthanum

Accuracy of Various Analytical Techniques

Lower Detection Limits for Semiquantitative OES Analysis.

ELEMENTS	DETECTION LIMIT (%)	ELEMENT	DETECTION LIMIT(%)
Al	0.001	Mo	0.001
Ag	0.001	Na	0.4
As	0.1	Nb	0.007
Au	0.002	Ni	0.002
B	0.002	P	0.2
Ba	0.07	Pb	0.01
Be	0.001	Pt	0.005
Bi	0.004	Re	0.005
Ca	0.02	Sb	0.04
Cd	0.04	Sc	0.005
Co	0.002	Si	0.003
Cr	0.001	Sn	0.002
Cu	0.001	Sr	0.06
Fe	0.002	Ta	0.008
Ga	0.002	Te	0.8
Hf	0.008	Ti	0.001
In	0.01	Ti	0.2
La	0.01	V	0.003
Li	0.1	Zn	0.1
Mg	0.004	Zr	0.004
Mn	0.001	Y	0.001

Grain Sizes of Earth Materials - Modified Wentworth Scale

GRADE LIMITS				GRADE NAME	
Phi	mm	Inches	US Standard Sieve Series		
-12	4096	161.3			
				Very Large	
-11	2048	80.6			
				Large	
-10	1024	40.3			Boulders
				Medium	
-9	512	20.2			
				Small	
-8	256	10.1			
				Large	
-7	128	5.0			Cobbles
				Small	
-6	64	2.52	63 mm		
				Very Coarse	
-5	32	1.26	31.5 mm		
				Coarse	
-4	16	0.63	16 mm		
				Medium	Pebbles
-3	8	0.32	8 mm		
				Fine	
-2	4	0.16	No. 5		
				Very Fine	
-1	2	0.08	No. 10		
				Very Coarse	
0	1	0.04	No. 18		
				Coarse	
+1	0.500	0.02	No. 35		
				Medium	Sand
+2	0.250	0.01	No. 60		
				Fine	
+3	0.125	0.005	No. 120		
				Very Fine	
+4	0.062	0.0025	No. 230		
				Coarse	
+5	0.031	0.00125			
				Medium	
+6	0.016	0.0006			Silt
				Fine	
+7	0.008	0.0003			
				Very Fine	
+8	0.004	0.00015			
				Coarse	
+9	0.002	0.000075			
				Medium	
+10	0.001	0.000003			Clay Size
				Fine	
+11	0.0005	0.0000015			
				Very Fine	
+12	0.00025	0.00000075			

Weights of Various Rock Materials

Material	Density	SOLID			BROKEN	
		Lb/ Cu. Ft	Cu. Ft/ Ton	Tons/ Cu. Yd.	Lb/ Cu. Ft	Cu. Ft/ Ton
Andesite	2.4-2.8	160	12.5	2.16	114.3	17.5
Anorthosite	2.6-2.9	170	11.8	2.29	121.4	16.5
Basalt	2.7-3.2	185	10.8	2.50	132.1	15.1
Brucite	2.3-2.4	145	13.8	1.96	103.6	19.3
Coal Bituminous	1.2-1.5	85	23.5	1.15	60.7	32.9
Dolomite	2.8-2.9	180	11.1	2.43	128.6	15.6
Diabase	2.8-3.1	185	10.8	2.50	132.1	15.1
Diorite	2.7-3.0	180	11.1	2.43	128.6	15.6
Gabbro	2.9-3.0	185	10.5	2.50	132.1	15.1
Gneiss	2.9-3.0	168	11.9	2.27	96.0	20.8
Granite	2.5-2.8	165	12.1	2.23	117.9	17.0
Gypsum	2.3-3.3	175	11.4	2.37	125.0	16.0
Hematite	4.5-5.3	305	6.6	4.09	217.9	9.2
Limestone	2.4-2.9	165	12.1	2.23	117.9	17.0
Magnetite	5.0-5.2	320	6.3	4.29	228.6	8.8
Mica Schist	2.5-2.9	170	11.8	2.29	121.4	16.5
Norite	2.7-3.0	180	11.1	2.43	128.6	15.6
Nepheline Syenite	2.5-2.7	160	12.5	2.16	114.3	17.5
Peridotite	3.1-3.3	200	10.0	2.7	142.9	14.0
Porphyry	2.5-2.6	160	12.5	2.16	114.3	17.5
Quartz	2.65	165	12.1	2.23	117.9	17.0
Quartzite	2.4-2.8	160	12.5	2.16	114.3	17.5
Rock Salt	2.1-2.6	145	13.8	1.96	103.6	19.3
Rhyolite	2.4-2.6	155	12.9	2.09	110.7	18.1
Sandstone	2.0-2.8	150	13.3	2.03	107.1	18.7
Shale	2.4-2.8	160	12.5	2.16	114.3	17.5
Siderite	3.0-3.9	215	9.3	2.90	153.6	13.0
Slate	2.5-2.8	165	12.1	2.23	117.9	17.0
Talc	2.6-2.8	170	11.8	2.29	121.4	16.5
Trap Rock	2.6-3.0	175	11.4	2.37	125.0	16.0
Tuff	2.0-2.6	145	13.8	1.96	103.6	19.3

Weights of Rock, Quarry, and Construction Materials

MATERIAL	Pounds/ Cubic Yard (BANK)	(LOOSE)	% Swell
Caliche	2430		
Cement, Portland	2700	2250	20
Cinders, Blast Furnace	1540		
Coal, Ashes & Clinkers	1080		
Clay, Compact Natural Bed	2040	2210	33
Clay, Dry Excavated	1850		
Clay & Gravel, Dry	2700	1930	40
Clay & Gravel, Wet	3090	2200	40
Coal, Anthracite	2300	1700	35
Coal, Bituminous	1900	1410	35
Coke		650- 850	
Concrete	3240-4100	2330-2950	40
Concrete, Wet		3500-3700	
Copper Ore	3800	2800	35
Earth, Dry Loam	2100	1550-1830	15-35
Earth, Moist	2700	2080-2250	20-30
Earth, Wet	3370	2700-2800	20-25
Earth, Sand, & Gravel	3100	2640	18
Earth & Rock	2500-3200	1920-2460	30
Granite	4500	2520-3000	50-80
Gravel, Dry, Loose		2570	
Gravel, Wet, Loose		3200	
Gravel, Dry, ¼" to 2"		2840	
Gravel, Wet, ¼" to 2"		3380	
Gravel, Pit Run, (Graveled Sand)		3240	
Gypsum	4500	2700	65
Limestone	4400	2660	65
Rock, Well Blasted	4000	2680	50
Sandstone	3000	2600	50
Sand, Dry	3250	2900	12
Sand, Moist	3400	2980	14
Sand, Wet	3600	3250	14
Sand & Gravel, Dry	3320	2920	14
Sand & Gravel, Wet	3900	3380	16
Shale, Riprap	2800	2100	33
Slag	3670	2970	24
Stone, Crushed	3240-3920	2400-2900	35
Taconite	4050-5400	2900-3860	40
Trap Rock	5000	3340	50

Average Density, Weight, and Volume of the Common Ore and Gangue Minerals

Average Density, Weight and Volume of Common Ore Minerals

Rock	Specific Gravity	Pound per Cubic Foot	Cubic Feet per Short Ton
Anglesite	6.20-6.40	386-400	5.00-5.17
Argentite	7.30	455	4.38
Arsenopyrite	6.07	379	5.28
Azurite	3.77	236	8.47
Bentonite	2.50	156	12.82
Bornite	5.06-5.08	316-318	6.30-6.33
Carnotite	4.10	256	7.81
Cassiterite	6.80-7.10	425-043	4.50-4.70
Cerussite	6.55	408	4.90
Chalcocite	5.50-5.80	344-362	5.52-5.81
Chalcopyrite	4.10-4.30	253-269	7.43-7.91
Chromite	4.60	288	6.94
Chrysocolla	2.00-2.40	125-150	13.3-16.0
Cinnabar	8.10	505	3.95
Cobaltite	6.33	396	5.05
Copper	8.95	556	3.58
Cuprite	6.00	375	5.33
Enargite	4.43-4.45	276-278	7.23-7.24
Galena	7.40-7.60	426-465	4.30-4.70
Garnierite	2.20-2.80	138-175	11.43-14.49
Gold	15.0-19.30	938-1206	1.66-2.13
Goethite	4.37	272	7.35
Gypsum	2.32	145	13.79
Halite	2.16	135	14.81
Hematite	5.26	328	6.10
Hemimorphite	3.40-3.50	212-219	9.20-9.45
Limonite	3.60-4.00	213-238	8.40-9.40
Magnetite	5.18	329	6.08
Malachite	3.90-4.00	243-250	8.00-8.20
Marcasite	4.89	306	6.54
Millerite	5.30-5.70	331-356	5.62-6.04
Molybdenite	4.62-4.73	289-296	6.76-6.92
Orpiment	3.49	218	9.17
Pentlandite	4.60-5.00	288-312	6.40-7.00
Perlite	2.20-2.40	137-150	13.33-14.60
Platinum	21.45	1340	1.40
Proustite	5.55	347	5.76
Pyrargyrite	5.85	366	5.46
Pyrite	5.02	314	6.37
Pyrrhotite	4.58-4.65	286-290	6.90-7.00
Realgar	3.48	218	9.17
Scheelite	5.90-6.10	396-381	5.25-5.49
Silver	10.50	655	3.14
Smithsonite	4.35-4.40	272-275	7.30-7.40
Sperrylite	10.58	661	3.03
Sphalerite	3.90-4.10	244-253	7.80-8.20
Stannite	4.40	275	7.00
Stibnite	4.52-4.62	283-289	6.92-7.07
Sylvite	1.99	124	16.13
Talc	2.80	175	11.29
Tennentite	4.60-5.10	288-319	6.27-6.94
Tetrahedrite	4.60-5.10	287-319	6.27-6.95
Uraninite	9.00-9.70	563-606	3.30-3.55
Vanadinite	6.70-7.10	419-444	4.50-4.77
Wolframite	7.00-7.50	438-469	4.26-4.57

Average Density, Weight, and Volume of the Common Ore and Gangue Minerals

Average Density, Weight, and Volume of Common Gangue Minerals

Anhydrite	2.89-2.98	181-186	10.75-11.05
Ankerite	2.95-3.00	184-188	10.64-10.87
Barite	4.50	280	7.12
Calcite	2.72	170	11.80
Dolomite	2.85	178	11.25
Magnesite	3.00-3.20	188-200	10.00-10.64
Quartz	2.65	166	12.20
Rhodochrosite	3.45-3.70	2.60-225	8.89-9.26
Rhodonite	3.58 3.70	224-231	8.66.8.93
Siderite	3.80	240	8.38

Diamond Drill Core Sizes and Hole Volumes

Drill Series	Core Diameter Inches	Hole Diameter Inches	Hole Volume Gal/100 Ft
EW	0.845	1.485	9.0
WG	1.185	1.890	14.6
WG	1.655	2.360	22.7
NWG	2.155	2.980	36.3
HWG	3.000	3.907	62.3
RWT	0.735	1.175	5.6
EWT	0.905	1.485	9.0
AWT	1.281	1.890	14.6
WT	1.750	2.360	22.7
WT	2.313	2.980	36.3
HWT	3.187	3.907	62.3
2 3/4 x 3 7/8	2.690	3.875	61.2
4 x 5 1/2	3.970	5.495	123.4
6 x 7 3/4	5.970	7.750	245.1
AQ	1.062	1.890	14.6
BQ	1.432	2.360	22.7
NQ	1.875	2.980	36.3
HQ	2.500	3.782	58.3
PQ	3.344	4.828	95.1
EX	0.875	1.500	9.2
AX	1.125	1.875	14.3
BX	1.625	2.375	23.0
NX	2.125	3.000	36.7

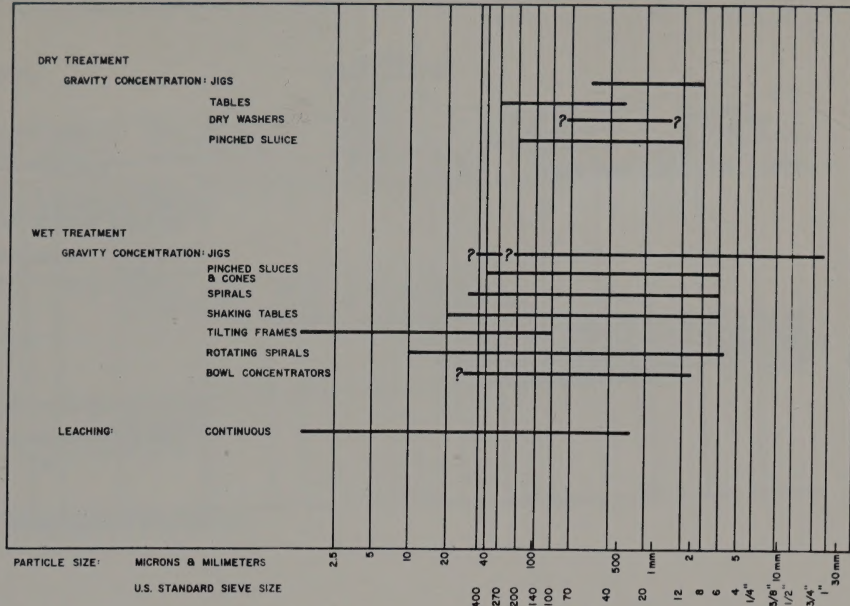


Table 1. Range of particle sizes effectively treated by various types of separation equipment. *Modified from Mildren, 1980.*

Reprinted from Silva, M (1986): Placer Gold Recovery Methods; Special Publication 87; Calfornia Division of Mines and Geology, pg 23.

Drill Log Assay and Value Calculations

Form 3980-6
(September 1983)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SUMMARY DRILL LOG

Location SE¼; S4; T6N; R7E
Latitude 150+00S
Departure 145+00W
Elevation 615' ASL

Azimuth 015°
Inclination -45
Depth 475'
Core Size BQ

Tests -45 @ 100'
-40 @ 250'
-36 @ 375'
-30 @ 450'

Case Serial No. ES -1524
Claimant Name St. Joe Minerals
Claim Name PRLA # ES- 1524
Claim Serial No. N/A

Sheet 1 of 1
Hole No. SJM-25
Logged by H Q Hammer
Date 7/13/83

SUMMARY LOG				ASSAY DATA												CALCULATIONS				
FROM	TO	ROCK TYPE	DESCRIPTION	SAMPLE NUMBER	FROM	TO	INTERVAL	oz/t Au	oz/t Ag	% Cu	% Zn	% Pb				INTERVAL (x) ASSAY	AVERAGE* INTERVAL	AVERAGE** GRADE	METAL PRICE	VALUE OF INTERSECTION
0'	75'	Overburden	Till, sand, clay																	
75'	110'	Felsic Tuff	Fol. @ 70° to CA																	
110'	175'	Andesite	Massive Flows Bedding @ 75° to CA																	
175'	190'	Chert	Banding @ 70° to CA																	
190'	275'	Massive Sulphides	Banding @ 50 CA Py+Cp+Sp+Gn Py(75%); Cp(5%); Sp(10%); Gn(10%)	HQH-1	190	210	20	.05	3.20	0.50	1.23	0.75								
				HQH-2	210	220	10	.04	5.10	0.64	6.43	2.75								
				HQH-3	220	245	25	.15	4.25	1.23	5.15	1.27								
				HQH-4	245	260	15	.12	6.11	3.45	6.05	1.08								
				HQH-5	260	275	15	.25	1.25	6.12	2.25	0.15								
							85	Au								10.70	17	0.13/oz.	$425./oz	$ 53.50Au
									Ag							331.65	17	3.90/oz	$11.35/oz	$ 44.29Ag
										Cu						190.70	17	2.24 %	$ 0.85/lb	$ 38.08Cu
											Zn					342.23	17	4.03 %	$ 0.42/lb	$ 33.82Zn
												Pb				91.95	17	1.08 %	$ 0.21/lb	$ 4.54Pb
													TOTAL VALUE OF INTERSECTION							$174.23
275'	400'	Rhyolite	Massive with QTZ eyes, altered to Chlorite+sericite																	
400'	475'	Andesite	Flows & Flow Bx Fol. @ 60 CA																	
	EOY																			

* Average Interval = Summation of intervals ÷ number of samples
** Average Grade = Summation of (interval × assay) ÷ summation of intervals

Drill Log Assay and Value Calculations

Form 3980-6
(September 1983)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SUMMARY DRILL LOG

Location SW¼; S4; T6N; R10W
Latitude 4+00N
Departure 7+00E
Elevation 750' ASL

Azimuth 235°
Inclination -75
Depth 550'
Core Size AQ

Tests -70 @ 100'
-70 @ 200'
-65 @ 350'
-60 @ 500'

Case Serial No. UT- 12501
Claimant Name A J Golddigger
Claim Name ~~Moonstone~~
Claim Serial No. UTMC- 110041

Sheet 1 of 1
Hole No. MS-12
Logged by H Q Hammer
Date 5/15/83

SUMMARY LOG				ASSAY DATA												CALCULATIONS				
FROM	TO	ROCK TYPE	DESCRIPTION	SAMPLE NUMBER	FROM	TO	INTERVAL	oz/t Au	oz/t Ag	% Cu	% Zn	% Pb				INTERVAL (x) ASSAY	AVERAGE* INTERVAL	AVERAGE** GRADE	METAL PRICE	VALUE OF INTERSECTION
0'	100'	QTZ PORH	Foliation @ 75°																	
			to Core Axis (CA)	HQH-1	45	50	5	.12								0.60				
			QTZ Vein from	HQH-2	50	55	5	.10								0.50				
			45' to 78' @	HQH-3	55	70	15	.08								1.20				
			70° to CA	HQH-4	70	78	8	.18								1.44				
							33'									3.74	8.25	0.11	$425.00/oz.	$ 46.75
100'	300'	Grey Schist	Foliation @ 60° to CA/ minor QTZ veins present																	
300'	350'	QTZ PORH	Shearing @ 65°																	
			to CA/ QTZ vein	HQH-5	340	345	5	.38								1.90				
			from 340'-350'	HQH-6	345	350	5	.45								2.25				
							10'									4.15	5.00	0.42	$425.00/oz.	$178.50
350'	450'	Banded Iron Fm	Banding @ 55° to CA																	
450'	550'	Blue Quartzite.	Bedding @ 55° to CA																	
Average	Value	for the Hole					43'									7.89	7.17	0.18	$425.00/oz.	$ 76.50
ACTUAL	VALUE	FOR THE HOLE																		$225.25

* Average Interval = Summation of intervals ÷ number of samples
** Average Grade = Summation of (interval × assay) ÷ summation of intervals

Form 1221-2
(June 1969)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

MANUAL TRANSMITTAL SHEET

Release
3-234

Date
3/17/89

Subject

H-3890-1 - HANDBOOK FOR MINERAL EXAMINERS

1. Explanation of Material Transmitted: This release updates and revises the existing Handbook for Mineral Examiners, H-3890-1. The revisions are based on the commentary submitted by the Field Offices and on recent Departmental rulings on mining claim contests. The criteria contained herein are mandatory in mineral examinations. The Handbook is being issued in a pocket edition for effective use in the field. An 8 1/2 x 11 - inch edition will not be issued.

2. Reports Required: None.

3. Material Superseded: The Material superseded by this release is listed under "REMOVE" below. No other directives are superseded.

4. Filing Instructions: File in the "red binder" Manual sets with Manual Section 3890. Use the existing special binders previously provided to house the Handbook.

REMOVE:		INSERT:
Title Page (Rel. 3-104)		Title Page
i	"	i
Table of Contents	"	Table of Contents
Chapter I	"	Chapter I
Chapter II	"	Chapter II
Chapter III	"	Chapter III
Chapter IV	"	Chapter IV
Chapter V	"	Chapter V
Chapter VI	"	Chapter VI
Chapter VII	"	Chapter VII
Chapter VIII	"	Chapter VIII
(Total: 33 Sheets)		(Total: 33 Sheets)

Hillary A. Oden

Assistant Director, Energy and
Mineral Resources

H-3890-1 - HANDBOOK FOR MINERAL EXAMINERS

Chapter 1

CHAPTER I. Introduction

1. The Authority of the Secretary of the Interior Under the Mining Laws.

The authority of the Secretary of the Interior with respect to public lands is set forth in Cameron v. United States, 252 U.S. 450, (1920), where the U.S. Supreme Court said:

> "By general statutory provisions, the execution of the laws regulating the acquisition of rights in the public lands and the general care of these lands is confided to the Land Department, as a special tribunal; and the Secretary of the Interior as the head of the Department, is charged with seeing that this authority is rightly exercised to the end that valid claims may be recognized, invalid ones eliminated, and the rights of the public preserved.
>
> "The power of the Department to inquire into the extent and validity of the rights claimed against the Government does not cease until the legal title has passed. [The Department's] province is that of determining questions of fact and right under the Public Land Laws, of recognizing or disapproving claims according to their merits, and of granting or refusing patents as the law may give sanction for one or the other."

The authority to administer the mining law program has been delegated to the Director of the Bureau of Land Management (BLM) by the Secretary of the Interior. The Departmental Manual states that "The Bureau is responsible for mineral and realty activities on all the public lands and for mineral activities on large areas of Federal land managed by other agencies. This includes the administration of the General Mining Laws." (See 135 DM 1.3B and 235 DM 1.A.) The BLM's authority in this regard emanates from its succession to the duties and responsibilities of the General Land Office and the Grazing Service, through the Reorganization Plan No. 3 of 1946 (60 Stat. 1097) and the Reorganization Plan No. 3 of 1950 (64 Stat. 1262).

2. Duties of the Mineral Examiner.

A mineral examiner's role is varied but important, requiring a thorough knowledge of the public land laws, Departmental decisions, and case law that govern the management and development of the locatable mineral resources. A working knowledge of the mineral industry and of mineral property evaluation is essential.

Chapter I

The mineral examiner's professional reputation as well as that of the agency is "on the line" on every mineral examination performed. It is incumbent upon the mineral examiner to do a thorough professional examination and evaluation of each mining claim and mill site.

The mineral examiner's function is to apply the legal and technical standards issued by the Department, and to give an opinion as to whether the examined mining claims and mill sites have met those standards. If the standards have been met, then the mining claims and mill sites are deemed valid. If a mineral patent application is involved, the mining claims and mill sites are patented. If the standards have not been met, then contest action may be initiated. If a contest action is initiated, the mineral examiner will be required to testify as an expert witness for the Government.

The Department has made it clear what it expects from a mineral examiner. These standards are:

A. "A mineral examiner is obligated to make a careful and competent inspection of a mining claim in order to be able to testify meaningfully on the presence or absence of mineral discovery there." United States v. Gerald Hess, 46 IBLA 7 (1980).

B. "A mineral examiner is responsible for the determination of the validity of mining claims conflicting with nonmineral entries under the general public land laws, and when requested by other Federal agencies desiring clear title to lands for public purposes. An examiner is charged with the responsibility to conduct his examination with an open and impartial mind. All available literature that covers the geology, mineralization, mining history, and economics of the mineral commodities being examined should be reviewed by the mineral examiner prior to the field examination in order to allow a competent examination of the property." United States v. Janet B. Copple, et al., 81 IBLA 132 (1984).

C. "Where a Government mineral examiner offers his expert opinion that discovery of a valuable mineral deposit has not been made within the boundaries of a contested claim, a prima facie case of invalidity has been made, provided that such opinion is formed on the basis of probative evidence of the character, quality, and extent of the mineralization allegedly discovered by the mining claimant. Mere unfounded surmise or conjecture will not suffice, regardless of the expert qualifications of the witnesses . . . The admissibility of expert testimony in a mining claim contest is determined by the hearing examiner, who exercises a wide latitude of discretion in making these determinations." United States v. Wayne Winter, 78 ID 193 (1971).

D. In order to testify as an expert witness, the "...testifying mineral examiner must be an expert as to the marketability or value of the particular mineral." Rodgers et al v. James Watt, 726 F. 2d 376 (9th Ciruit, 1984) and cases cites therein.

A mining claim constitutes a possessory interest in the land, authorized by the Mining Law of 1872, as amended (30 USC 21-54). If the mining claim is valid, the mining claimant has possessory right to the mineral and the right to purchase the surface and mineral estates. This property right may not be extinguished without due process.

3. How To Conduct Yourself With The Public.

In dealing with the public, the mineral examiner will be asked to give advice or an opinion on many topics. The mineral examiner is not an attorney nor acting as a professional consultant. On legal questions, the mineral examiner should cite the applicable law, refer to pertinent decisions, and refer the person to an attorney for legal advice. When the question is of a technical nature, guard against giving information, advice, or suggestions which are not within the scope of your regulatory and statutory authority.

Frequently, mineral examiners are asked questions by mining claimants whose mining claims or mill sites are being investigated. In these instances, limit answers to those of general nature, or to an explanation of the procedures that will be followed. This is especially true in talking to mining claimants who have mining claims on land under the jurisdiction of other Federal agencies. The mineral examiner's job is to secure facts upon which the mineral examiner, in exercising professional judgment, can reach an opinion as to the validity of the mining claim or mill site. THE EXAMINERS JOB IS NOT TO ADJUDICATE THE RIGHTS OF THE PARTIES INVOLVED IN THE CASE. The importance of ensuring the public's understanding of the mineral examination process cannot be overemphasized.

One of the contacts that a mining claimant has with an agency is through the mineral examiner. The impression left with the mining claimant depends largely upon the manner and professionalism of the mineral examiner during the examination. The mineral examiner should be friendly and courteous at all times.

By inviting the mining claimant to accompany the mineral examiner during the validity examination the mining claimant has the opportunity to identify the discovery points and other places from which the mining claimant wishes samples to be taken. The mineral examiner may take samples from locations not selected by the mining claimant, if necessary, to adequately examine the mining claim. The mineral examiner should not discuss any opinions on the case nor imply any conclusions.

H-3890-1 - HANDBOOK FOR MINERAL EXAMINERS

Chapter II

CHAPTER II. Mineral Investigations

1. Validity Examinations.

To be valid, a mining claim must contain a discovery of a valuable mineral deposit subject to location under the Mining Law of 1872, as amended (30 USC 21-54).

A valid mill site is one that is located on nonmineral land, and is being used for mining or milling purposes, or other uses reasonably incident to a mining or milling operation.

The "Prudent Man Rule" was first promulgated by the Interior Department in Castle v. Womble, 19 LD 455 (1894) and has been repeatedly affirmed by the Federal courts. See Chrisman v. Miller, 197 U.S. 313 (1905) and United States v. Coleman, 309 U.S. 599 (1968).

The "Prudent Man Rule" as stated in Castle v. Womble, supra; is:

> "Where minerals have been found and the evidence is of such a character that a person of ordinary prudence would be justified in the further expenditure of his labor and means, with a reasonable prospect of success, in developing a valuable mine, the requirements of the statute have been met. To hold otherwise would tend to make of little avail, if not entirely nugatory, that provision of the law whereby 'all valuable mineral deposits in lands belonging to the United States . . . are . . . declared to be free and open to exploration and purchase.' For, if as soon as minerals are shown to exist, and at any time during exploration, before the returns become remunerative, the lands are to be subject to other disposition, few would be found willing to risk time and capital in the attempt to bring to light and make available the mineral wealth, which lies concealed in the bowels of the earth, as Congress obviously must have intended the explorers should have proper opportunity to do."

The "Marketability Test," which is a compliment of the "Prudent Man Rule" and applies to all mining claims, was first applied by the Interior Department by Secretarial Opinion published at 54 LD 294 (1933). This supplemental requirement for a discovery has been affirmed by the Federal courts in Foster v. Seaton, 271 F. 2d 836, D.C. Circuit Court (1959); Converse v. Udall, 389 F. 2d 616, 9th Circuit Court (1968); and United States v. Coleman, supra.

The test of marketability is:

> . . . "a mineral locator or applicant, to justify his possession, must show that by reason of accessibility, bona fides in development, proximity to market, existence of present demand, and other factors, the deposit is of such value that it can be mined, removed, and disposed of at a profit." (54 LD 294, 1933).

The mineral examiner must exercise good professional judgment in evaluating the data that is pertinent to a discovery. Based on the actual mineral showing and its relationship to the geologic setting of the mineral district, the mineral examiner must decide if there is a discovery under the "Prudent Man Rule" and marketability requirements.

GEOLOGICAL INFERENCE, NO MATTER HOW STRONG OR CONVINCING, CANNOT BE USED AS A DISCOVERY IN PLACE OF A PHYSICAL EXPOSURE OF ACTUAL MINERAL IN PLACE. See McCall v. Andrus, 628 F. 2d 1185, 9th Circuit Court (1980); cert denied, 450 U.S. 996 (1981) and United States v. J. Gary Feezor, et al, 74 IBLA 56 (1983).

The Department has held that geophysical or geochemical data will not qualify as mineral discoveries without an associated physical exposure of the minerals claimed. Discovery of mineral in drill holes will qualify providing drill sites, drill logs, cores, and/or cuttings can be verified. Consult section IV-2D for further guidance on the use and handling of drill core.

Although the regulations at 43 CFR 3860 provide that the point of discovery must be designated on the mineral survey plat, the actual discovery need not have been made in the "discovery working." A discovery of mineral under the "Prudent Man Rule" must be made within the boundaries of each mining claim.

2. Mineral Land Determinations.

In the mineral examination of mining claims and mill sites, the question of mineral land has to be answered in two specific contexts.

A. A mill site must be located on nonmineral land.

B. In addition to a discovery on an association placer claim, each square 10-acre legal subdivision of an association placer claim must be mineral land (mineral-in-character) in order to sustain the location. This is the "10-acre rule" which has been required by the Department since 1899. See United States v. Charles H. Henrikson et al, 70 ID 212 (1963). These requirements are further described in Chapter III-7 and III-8.

The Department's position in relating to mineral land determinations is fully stated in Southern Pacific Co., 71 ID 224, 233 (1964):

> "It is sufficient to show only that known conditions are such as reasonably to engender the belief that the land contains mineral of such quality and in such quantity as to render its extraction profitable and justify expenditures to that end. Such belief may be predicated upon geological conditions, discoveries of minerals in adjacent land, and other observable external conditions upon which prudent and experienced men are shown to be accustomed to act."

3. Valuation of Mineral Properties.

Valid mining claims or mill sites on public land or interest in land, in areas which are later required by the United States for a Federal highway right-of-way, various reclamation projects, military reservations, and other single resource uses, must be appraised for purchase or for condemnation. In addition to appraising mining claims and mill sites, the mineral examiner is often required to appraise deposits of mineral materials, such as sand, gravel, stone, pumice, and other common variety mineral materials. The locatable and salable minerals must also be appraised for fair market value for conveyance under Section 209 of the Federal Land Policy and Management Act of 1976. The valuation process is given in Chapter V-9.

4. Public Law 167.

The Surface Resources Act of July 23, 1955, Public Law 84-167 (30 U.S.C. 611-615), provides a procedure whereby the United States may resolve surface rights to unpatented mining claims located prior to the act. Mining claims located after July 23, 1955, are subject to the provisions and limitations of the act including the right of the United States to manage the surface resources.

Even though the United States may gain the right to manage the mineral material and vegetative surface resources under the proceedings of PL-167, the mining claimant does not lose any possessory rights to the locatable minerals or to the use of as much of the surface as is reasonably necessary to sustain the operations. Furthermore, any permittee or licensee of the United States or user of the public land may not endanger or materially interfere with prospecting, mining, or processing operations or uses reasonably incident thereto.

5. Multiple Use Conflicts.

Mining claims and mill sites often conflict with land disposal or other actions such as desert land entries, material sale sites, range-improvement projects, timber sales, withdrawals, or rights-of-ways. Validity examinations are sometimes required to resolve these conflicts after all other legal remedies have been exhausted.

Validity examinations are not required to resolve occupancy trespasses on mining claims located under the guise of the mining law. An administrative contest action against an unauthorized surface use of a mining claim or site can now be instigated by the Bureau, so that a validity examination is unnecessary. The contest action is filed under the provisions of 43 CFR 3712.1. This type of action and Departmental precedent is covered in Bruce W. Crawford et ux., 92 ID 208, 237 (1985) and Bureau Manual Section 3893. As a last resort, a civil action may be prosecuted against unauthorized uses of a mining claim in the Federal courts under 30 U.S.C. 612 without having to perform a validity examination. See United States v. Edison R. Nogueira et al., 403 F. 2d 816 (9th Circuit 1968).

6. Mining Claims and Leasable Minerals.

From 1924 to 1954, the Department has held that a lease application, the issuance of a prospecting permit, or a formal classification of land as valuable for a leasing act mineral, segregates the land from mineral entry under the mining laws. See Joseph E. McClory, 50 ID 623 (1924) and Secretarial Opinion at 50 ID 650 (1924). Under certain conditions, land was reopened and mining claims recognized by the passage of PL-250 (30 U.S.C. 501-505) and PL-585 (30 U.S.C. 521-531), providing the recordation requirements of these acts were followed.

These acts allow for the acceptance of mining claims located on land segregrated by the Secretary under 50 ID 650. The following table shows the effects of these acts to the rights of mining claimants:

Classification of Mining Claims Under Public Law 585

Mining claims or mill sites located on or before August 13, 1954, on vacant lands later covered by mineral leases or permits.	valid
Mining claims or mill sites located on or before July 31, 1939, on lands covered by mineral leases or permits or applications for same or known to be valuable for leasable minerals.	invalid

Mining claims or mill sites located between August 1, 1939, and February 10, 1954, on land covered by mineral leases or permits or applications for same or known to be valuable for leasable minerals.	valid only if compliance with the provisions of PL-250 and/or PL-585.
Mining claims or mill sites located between February 10, 1954, and August 13, 1954, on land covered by mineral leases or permits or applications for same or known to be valuable for leasable minerals.	invalid
Mining claims or mill sites located after August 13, 1954, on lands covered by mineral leases or permits or applications for same or known to be valuable leasable minerals.	No conflict because of separation of rights to locatable and leasable minerals.

7. Mining Claim Recordation.

On October 21, 1976, the Federal Land Policy and Management Act (FLPMA) was enacted (43 U.S.C. 1701 et seq.). Section 314 of FLPMA (43 U.S.C. 1744) established a Federal recordation system for mining claims, mill sites, and tunnel sites. All existing mining claims, mill sites, and tunnel sites had to be recorded with the proper Bureau of Land Management State Office by October 22, 1979, or they were, by statute, declared abandoned and void. Each mining claim, mill site, or tunnel site located after October 21, 1976 must be recorded within 90 days of location date or become abandoned and void. The constitutionality of Section 314 of FLPMA was upheld in its entirety by the U.S. Supreme Court in United States v. Madison Locke et al., 471 U.S. 84, 129 (1985).

The act also requires that during EACH CALENDAR YEAR, following the calendar year in which the mining claim was located, the owner(s) of each mining claim must file an affidavit of assessment work or a notice of intent to hold with the Mining Claim Recordation Section in the proper State Office; otherwise by operation of law it is declared abandoned and void. The Department of the Interior, by regulation, extended this requirement to include mill sites and tunnel sites. This second requirement is a curable defect.

The annual filings for mining claims must also be recorded in the local recording office. Mill sites and tunnel sites are not subject to this requirement. Each State Office maintains microfiche and computer files on all mining claims and sites recorded in the area administered by that office.

CHAPTER III. Mineral Examination Procedures

1. Preparation for a Validity Examination.

The case file should be carefully examined, making certain that it contains all available pertinent case history. Land status information that may be required should be requested from the BLM State Office having jurisdiction over the case. The Historical Index is to be examined for Public Land Orders, classification actions, and other pertinent data that would have caused the mining claim or site to be null and void ab initio.

A copy of the mineral survey plat and notes, if available, should be obtained from the BLM State Office and the survey notes checked for pertinent data. The mining claim recordation data should also be checked.

A topographic map, preferably a 7.5 minute series (scale 1 inch to 2,000 feet), should be enlarged to a scale of at least 1 inch to 400 feet, and used to plot the necessary field data for the field examination. Do not use the official copies of the Master Title Plat. In some instances, it may be useful to use a copy of the Mineral Survey Plat, enlarged to a scale of at least 1 inch to 400 feet.

An important tool for field examination are aerial photographs, preferably at a scale of 1 inch to 1,320 feet or greater. Coverage is available for most of the continental United States and can be obtained through the BLM's Cadastral Survey office, from the national aerial photograph library at the EROS Data Center in Sioux Falls, South Dakota, or from the U.S. Department of Agriculture Aerial Photography Field Office in Salt Lake City, Utah. Air photos can be enlarged and used as base maps if topographic maps are not available.

All available literature concerning the geology, mineralization, mining history, and economics of the mineral commodities being investigated should be reviewed. The best available sources of information are the Geological Survey, local State Geological Survey, the Bureau of Mines, university libraries, and local geological societies.

For publically owned entities, or those properties that are being worked by a publically owned entity, the examiner should request copies of prospectuses, annual reports, and related documents that they are required to file with the Securities and Exchange Commission (SEC). Such documents will include statements concerning the reserves on the property and must be backed up by evaluation reports by the company. Questions concerning the material filed with the SEC can be addressed to the SEC's Office of Fngineering in Washington, D.C. or its Branch of Geology at the Denver Regional Office.

All equipment should be carefully checked before going into the field to be sure that everything is functioning properly. Make certain that your compass is set to the proper magnetic declination as given on the USGS topographic map.

Only clean sample bags are to be used to avoid contaminating the samples. Chisels and moils should be sharp. Standard sample form (3980-3) should be used to identify the samples. The use of this form will assist in avoiding errors at a later date.

A 35-millimeter camera should be used to PHOTOGRAPH ALL SIGNIFICANT FEATURES OF THE MINING CLAIM OR MILL SITE (discovery point, sampling points, improvements, and equipment). Photographs at a contest hearing can go a long way in convincing an administrative law judge of your point of view as to the particulars of a mining claim or mill site. Use a medium speed, black and white film or a color film with a good color contrast rating. Prints should be taken as opposed to slides. Some courts consider slides to be subject to tampering, and are therefore, suspect evidence.

All mapping should be done with the use of standard topographical, geologic, and mining symbols. Standard symbols are given in Dietrich et al. (1982), Compton (1962), Lahee (1951), and Appendix I, and should be used in all mineral reports.

2. Field Safety Checklist.

The following is a recommended checklist of items that are normally required for field safety in the examination of a mining claim:

A. Read and be familiar with the Mine Safety and Health Administration (MSHA) regulations, especially those in 30 CFR Chapter I, subchapters B, C, D, and H. You are required to follow these regulations when on a mining property.

B. Read Bureau Handbook H-1112-1 - Safety, pp 46-50.

C. Read Bureau of Mines Information Circular 7479.

D. Do not enter into underground mine workings alone, or onto any areas around surface mine workings in a casual manner. BE ALERT AND REMAIN ALERT.

E. When going underground, always carry and wear appropriate equipment which shall include at a minimum:

(1) Approved hard hat with electrical resistance.

(2) Sturdy over-the-ankle boots or safety boots. Steel toes are usually required.

(3) If going underground, three different sources of light (battery powered head lamp, flashlight, penlight, candle wrapped in aluminum foil, matches in waterproof container) should be carried.

(4) Drinking water.

(5) Rock Pick.

(6) Safety glasses for use in rock breaking and sampling.

(7) MSHA Self-Rescuer (Respirator W 65 for self-rescue from carbon monoxide) for underground work.

(8) Small personal first-aid kit.

F. In cases where there is a question about entering into underground mine workings, or onto areas around surface mine workings, the decision will rest with the mineral examiner. UNDERGROUND WORKINGS SHOULD NOT BE ENTERED ALONE.

G. Always tell someone where you are going and when you expect to return.

3. Field Notes.

The importance of adequate and legible notes cannot be overemphasized. Geologic shorthand should use standard abbreviations such as given in Compton (1962) or in Dietrich et al. (1982). Use an engineer's field book with water resistant pages for taking field notes. The field notes are photo copied and placed in the case file. The mineral examiner should always keep a reserve copy of the field notes in the event the file copy is lost.

If more than one mineral examiner participates in the examination, one mineral examiner should be designated as the official note recorder and the other as the lead mineral examiner. However, all should take notes to avoid any confusion that may occur in the office when the joint mineral report is being written.

Notes taken in the field should be recorded in sequence as the investigation progresses. Use the checklist below to guide the examination, as well as to help standardize note taking. It will also help minimize the possibility of overlooking pertinent data that should be recorded while in the field.

4. Checklist for Field Notes.

A. General.

(1) Identify each participant involved in the field examination.
(2) Each page of the field notes must be dated and numbered.

B. Physical Features.

(1) Location: direction and distance from nearest town, mining district, county, and State.
(2) Accessibility: how reached, transportation facilities, etc.
(3) Topography: general description, elevations.
(4) Vegetation and timber, general climate.
(5) Water and power facilities, as appropriate.
(6) Identification of the land and/or mining claims or mill sites.
(7) Current usage of the subject land, mining claim, or mill site.

C. Geology and Mineral Deposits.

(1) General geology of the land involved (relate to the geologic setting).
(2) Structural details.
(3) Mineralization: valuable minerals, gangue minerals, description of veins or lodes, alteration zones.
(4) Ore reserves: tonnage and grade.
(5) Mill sites: mineral or nonmineral land, use of the mill site, source of ore.
(6) Does the mineral deposit fit any known ore model.

D. Mineral Development.

(1) Describe surface and underground workings, drill core and/or cuttings (relate to surface and subsurface geology and structure), prepare geologic map of surface/subsurface, or verify data on existing maps, discuss past and present production.
(2) Industrial plants and equipment: describe type and present use of buildings, improvements, and equipment.
(3) Estimate value and utility of plant and equipment.
(4) For a mineral patent application, give estimated value of all qualifying expenditures.

E. Sample Data.

(1) Index samples from the sample tags (elaborate on information included on sample tags, when necessary).
(2) Describe and photograph sample site and describe collection procedure in detail, dimensions of sample cut, and relationship to the mineral deposit. Relate sample to the mining claim from which it was taken.
(3) Give geologic setting of sample site (structure and lithology) and reason(s) sample was collected at that site. Plot sample site on map.

(4) Describe how samples were protected from site to assayer's office. Show "chain of custody." If the BLM office does not have adequate, secured storage facilities, then have assayer hold sample splits until all administrative actions are completed and appeal periods have expired. The assay pulps should also be held in the same manner.

F. Other Pertinent Data to be Identified.

(1) Mining claim or mill site monuments, discovery point on lode line, orientation of the mining claim to the vein or lode, etc.
(2) Posting of mineral survey plat and notice of patent application (when applicable), photograph and date field verification of posting. Posting need only be done during the 60-day publication period.
(3) Conflicts between mining claimants.
(4) Dummy locators.
(5) Compliance with applicable State and local laws.
(6) Placer mining claims conforming to legal subdivisions, when appropriate.
(7) Mineral character of each square 10-acre legal subdivision of association placer claims (the "ten-acre rule").
(8) Photographs properly indexed and titled.
(9) Persons interviewed. Give names, addresses, telephone numbers, and dates.
(10) Mill sites; describe use and relationship to associated mining claims. If a custom mill site, describe the milling equipment and identify the source of ore.

5. <u>The Field Examination</u>.

The mining claimant shall be notified of the pending examination at least 30 days before the proposed date of the mineral examination. The notification shall be sent by certified letter, return receipt requested. Prior to notification, contact the mining claimant by telephone to establish a date that is mutually agreeable. The mining claimant must be invited to accompany the mineral examiner to point out discovery point(s) and other pertinent features of the mining claim or mill site. The mining claimant may designate an agent to appear in his/her place. Failure to properly notify the mining claimant of the pending mineral examination may subject the government to having its case dismissed by an Administrative Law Judge if a contest action is initiated. Ask the mining claimant to make available any data pertaining to production, mining costs, marketing arrangements, geology, and character of the mineral deposit.

Strive for amicable entry and examination of the mining claim or mill site. However, if the mining claimant threatens the mineral examiner or uses force to prevent the mineral examiner from going onto the mining claim or mill site, notify your supervisor immediately. On BLM administered lands, also notify the Special Agent. If these officials are unable to get the mining claimant's agreement for a mineral examination, the U.S. Marshall's Office should be requested to provide protection. To obtain the the U.S. Marshall's assistance, it may be necessary to work through the office of the U.S. Attorney. In many cases, cooperation may be obtained through the effort of the local mining association.

The first step in a mineral examination is to locate the boundaries of the mining claim or mill site. Major pertinent features are recorded on the topographic map. The geology and cultural features are recorded on the map as the reconnaissance is made. The mineral survey plat (if required) and survey notes should be compared with the monuments and workings on the mining claim.

The reconnaissance acquaints the mineral examiner with the area and facilitates planning and execution of an efficient mineral examination. When examining a mining claim, to determine whether or not a discovery has been made, the mineral examiner must bear in mind that his/her job is not to make a discovery, but only to verify that a discovery has been made by the mining claimant. THE DISCOVERY POINTS MUST BE AVAILABLE AND SAFE FOR EXAMINATION. If the alleged discovery is in a shaft or other underground working which is inaccessible or unsafe to enter, the mineral examiner need not try to make the discovery accessible or enter under unsafe conditions. If the mining claimant refuses to make the discovery points accessible, sample other parts of the mining claim as a backup for future actions. Document tne mining claimant's assertions that a discovery exists at a specific point on the mining claim.

All accessible discovery points should be carefully examined and mapped; show all geologic structures, their attitudes, and plot all sample points. If the discovery is underground, map all subsurface features. See Peters (1978, pp 339-360). Collect a sufficient number of samples to allow the verification of grade and tonnage of the mineral deposit. See chapter V-2 of this Handbook for details of grade and tonnage calculations.

6. Lode Mining Claims.

All manmade structures and improvements should be plotted on the base map. Surface geologic structures should be plotted on the map and correlated with the geologic structures exposed in the discovery shaft, cuts, pits, workings, and other points of exposure. Additional information should include a description of the valuable minerals, gangue minerals, vein and wallrock alteration, and the country rock. Establish whether the deposit is similar to others in the general area. Published data of the mines in the district are helpful in evaluating the mineral deposit under investigation. A detailed description of all workings and improvements on each mining claim is essential. If the side or end lines of a lode claim are extended onto land not open to mining claim location in order to obtain extralateral rights, the discovery must be on that portion of the land open to mining claim location. See Marilyn Dulton Hansen, 79 IBLA 214 (1984) and Santa Fe Mining Co., 79 IBLA 48 (1984). A lode claim is limited by statute (30 U.S.C. 23) to a length of 1500 feet along the vein and a width of 300 feet on each side of the vein.

7. Placer Mining Claims.

All manmade structures and improvements should be plotted on the base map. The geologic formations or units carrying the recoverable values or commodities should be mapped.

A discovery must exist within each placer mining claim. Each square 10-acre parcel of a placer mining claim must be shown to be mineral-in-character. See United States v. Robert B Lara, [On Reconsideration], 80 IBLA 215 (1984); affr'm, Lara v. United States, (9th circuit, July 8, 1987). When a mineral patent application is involved, any square 10-acre parcel that is not mineral-in-character must be omitted from the patent application by the applicant or the 10-acre portions(s) may be subject to contest action by the United States. For irregular shaped placer claims, the 10-acre tracts are created by dividing the claim in half down its long axis and forming 10-acre parcels (they don't have to be square if claim geometry will not permit it) out of the divided portions.

Placer mining claims not located in conformance with the public land survey (gulch placers) are permitted under special rules. See Snow Flake Fraction Placer, 37 LD 250, (1908); United States v. Charles H. Henrikson et al., 70 ID 212 (1963); and 43 CFR 3842.

The best sources for the appropriate techniques, equipment, and processing methods of detrital minerals from placer mining claims, are Wells (1968), Macdonald (1983), and Peele (1959, p. 533-640). These references should be consulted prior to starting a field examination on a placer mining claim which contains a discovery of detrital minerals.

8. Mill Sites.

There are two types of mill sites, associated (dependent) and custom (independent). An associated mill site is one associated with a lode or placer mining claim either patented or unpatented and to be valid, the associated mining claim, must be valid. A custom mill site is not associated with an identified mining claim and is an independent operation. A custom mill site is required by 30 U.S.C. 42 (b) to contain a "quartz mill or reduction works." In modern parlance this means any milling, flotation, or beneficiation facility (including smelters) for the processing of custom ores. The use of the mill site must be reasonably incident to, or in support of, a mining or milling operation. All buildings, settling ponds, spoil piles, and other structures associated with the operation, should be plotted and tied to the mill site corners or mineral survey corners.

Each mill site is limited to a maximum of 5 acres in size and must be located on nonmineral land. Mill sites may be located by legal subdivision or by metes and bounds. Any number of mill sites may be located but each must be used in connection with the mining or milling operation.

9. Tunnel Sites.

The Mining Law of 1872 (30 U.S.C. 27) authorized a means of subsurface exploration by tunneling. Tunnel sites are located and recorded in the same manner as mining claims. It grants to the claimants of the tunnel site the possession of all previously undiscovered veins or lodes that are intersected by the tunnel. A tunnel site is valid for a distance of 3000 feet from its originating face. The possession of all veins or lodes discovered in the tunnel extends outwards to 1500 feet in each direction along such vein or lode, taken from the center of the tunnel. To maintain possession of the lode or vein, a lode mining claim must be located on the surface trace of the lode or vein discovered in the tunnel. See Enterprise Mining v. Rico-Aspen Consolidated Mining Co., 167 US 108 (1895). A substantially horizontal drill hole will qualify as a "tunnel" on a tunnel site location.

Work on a tunnel must be diligently prosecuted and failure to perform work on the tunnel for over 6 months results in an abandonment of the owners rights to any undiscovered veins or lodes in the tunnel. Tunnel sites cannot be patented, but may be held indefinitely, provided that the work is being diligently prosecuted.

10. Mineral Patent Applications.

The mineral examiner should verify that a reasonable estimate of the value of improvements for each mining claim totals at least $500. Ensure that the Mineral Survey Plat agrees with the actual location of the mining claims, mill sites, and their improvements. If the placer mining claim or mill site is located by legal subdivision, verify the location of the placer mining claim or mill site.

If more than one mining claim is involved in a mineral patent application, the $500-expenditure need not have been made on each mining claim, but may be expended on one or more of a contiguous group of mining claims PROVIDED THAT THE IMPROVEMENTS MADE CLEARLY BENEFIT AND TEND TO DEVELOP THE GROUP AS A WHOLE. The total expenditures divided by the number of mining claims must be equal to at least $500. Mill sites are not subject to the $500 expenditure requirement.

If a mining claim is located over an earlier or abandoned mining claim, and an application for patent is made under the new location, any improvements or labor made under the senior location cannot be applied toward the $500-expenditure for patent.

The proper date for verifying a discovery (Prudent Man and marketability) on the claims contained in a mineral patent application, is the date of issuance of the first half of the mineral entry final certificate. See United States v. Norman A. Whittaker (On Reconsideration), 102 IBLA 162, 168 (1988).

CHAPTER IV. Sampling and Assay Procedures

1. General Sampling Procedures.

The mineral examiner has the responsibility of protecting samples from contamination or salting from the time of the sampling until the end of all administrative and legal proceedings, that is, maintaining a "chain of custody." Definite plans as to the handling, splitting, and the secure storing of the samples and of the pulps and rejects should be worked out in significant detail to assure reproducibility of the assay results. This is especially significant if the assay results are questioned later, or if the case ends up in litigation in the Federal courts. This precaution may avoid a return trip to the property for additional sampling and will support the mineral examiner's conclusions at a hearing.

The validity of a mining claim is directly related to the results of the sampling. The sampling method will generally be determined by the character of the mineral deposit to be sampled and not on how the mining claim is located in relationship to the mineral deposit. Samples should be representative of the entire mineral deposit.

2. Sampling of Rock in Place.

The mineral examiner, based on professional experience and judgment, must determine the method by which samples will be taken, using methods and techniques that are currently recognized as standard practice in the minerals industry.

Where the material to be sampled shows pronounced variation in composition due to banding, bedding, or in hardness, sample each variation separately to avoid overcompensating for variation. The amount of sample taken should be at least one pound per linear foot of material sampled.

Regardless of the type of sample taken, the area to be sampled must be thoroughly cleaned to avoid salting or dilution. For sampling material in place exposed to weathering, expose a fresh surface. If that is not feasible, the sampling face should be cleaned to remove all salts, oxides, or other contaminants. Use a drop cloth under the area to be sampled or use a sampling ring to ensure that you catch all of the sample material. Take large representative samples whenever possible. This reduces sampling error if mineralization is not of uniform distribution in the host rock.

The spacing of samples will be governed by the controlling factors of the material to be sampled. Controlling factors include variations in composition, vein dimensions, number of veins, outcrop exposure, and the number of discovery points and workings. In all cases sample form 3980-3 should be filled out; and any contingencies should be explained more fully on the back of the form or in the notes, with the proper reference number for the sample. The sample point should be photographed and/or sketched in your notebook. A card should be photographed on the sample point with the following information on the card:

A. Sample number
B. Date of sampling
C. Mining claim name and serial number
D. Initials of person taking the samples

Describe the geologic structure, the location and dimensions of the area sampled, and record any other information that will help in evaluating assays and calculating the ore grade. If the case ends up in a contest hearing or in court, a sketch along with a photograph of the sample point, before and after sampling, can be a strong influence in support of the examiner's professional opinion. If the assay results seem to be unusual or erratic, the sample site sketch may assist in the interpretation of the result. If resampling is necessary, the sketch will assist in the location of the confirmation sample.

If local conditions require a variance in sampling procedures from the following methods, then fully document the method used and the reasons why it was used. Consult McKinstry (1948), Parks (1957), and Peters (1978), for the appropriate methods of sampling.

A. Channel Samples.

Channel sampling requires the cutting of a uniform channel 3 to 6 inches wide and one or more inches deep across the section to be sampled. It is normally used where precision sampling is required or where mineral distribution is erratic. The sample is caught in a canvas sheet or tarp placed below the cut and is bagged and labeled. The method is applicable to all deposits.

B. Chip Samples.

Progressive chipping across the structure, in amounts proportional to the quantity of material in place, will closely approximate the results of a channel sample. Be careful that no material is lost. Use a canvas sheet or tarp to catch the chips. Chip sampling is normally used where the mineralized area is homogenous and uniform. Special care must be used where mineralization is not uniform to obtain a representative sample.

C. Grab Samples.

Although grab sampling may yield valuable information, it is not systematic or statistically valid. The mineral examiner should use grab sampling cautiously because unintentional high grading is always possible. Layering or segregation of mineral values may be present. Grab sampling is not recommended; it carries little probative value on the witness stand. Grade and tonnage figures are not reliable if calculated from grab samples.

D. Drill Core and Cuttings.

The driller's log and geologist's sample log should be available and examined concurrently with the core or cuttings, noting gaps or discrepancies in the core or cuttings. Assay logs and geophysical logs of the hole should be examined and any discrepancies noted. Core or cuttings that do not match the log or that appear to have been rearranged from their proper order should not be used to demonstrate a discovery.

If an unresolved discrepancy exists with respect to the core or cuttings, the drill hole can be logged by the use of an appropriate down hole instrument (such as an x-ray fluorescence or a neutron activation assay unit), if available, to verify the location, thickness, and quality of the minerals claimed for the discovery. Alternatively, a confirmation hole should be drilled by the mining claimant in the presence of the mineral examiner.

To sample drill core, cut the core in half lengthwise. Use a core splitter if one is available. Clean the splitter before each sample is split. If no core splitter is available, obtain a length of channel or angle iron, place the core into it, and split the core with a hammer and a sharp chisel. Assay lengths will be governed by the mineral distribution, geology, and structure in the core. As a rule of thumb, individual assay lengths should be 1 to 5 feet. If the mineralized portion of the core is greater than 5 feet, assay each 5-foot unit separately and then add the assay units together. (See Chapter V-5.) For porphyry copper and molybdenum deposits, where the mineralized zones may exceed 1,000 feet in width and depth, a 20- to 50-foot assay length is preferable, especially for making calculations.

Cuttings from rotary drills are normally bagged and stored in 5-foot intervals. A representative sample requires a sufficient amount of material from each sample interval to obtain a reliable assay from that interval.

3. Sampling of Placer Deposits.

Placer sampling is probably one of the most difficult and time-consuming tasks faced by a mineral examiner. The mineral examiner must consider the type of deposit; depth to bedrock; false bedrock; variation of silt, sand, and cobble size within the deposit; and quantity and physical characteristics of gold and other placer minerals.

The best placer sample yields limited information. The mineral examiner must rely upon the mining history of the area and on experience rather than a rigidly defined formula for interpretation of the sample data.

The sampling method may need to be modified from point-to-point as dictated by the characteristics and geology of the deposit. Where possible, the mineral examiner should use the same equipment and methods as the operator of the placer claim in order to properly evaluate the feasibility of the operation. Sampling is done by mechanical excavation, hand-dug exposures, or suction dredging. In extreme cases, drilling may be necessary. The sample size should be of sufficient volume to contain as many of the characteristics of the deposit as feasible and should not be less than one cubic foot of bank measure or 20 pounds per linear foot of depth sampled.

A calibrated bucket for sampling of placer mineral will save time and effort. If a suction dredge is used, it should be operated for at least one hour to obtain a proper sample and to allow the economics of the operation to be calculated on an hourly basis. To avoid salting, the face of a previously exposed sample trench should be cleaned to a depth of at least 4 inches before cutting the sample.

The large volume of a placer sample mandates that the sample be reduced to a more manageable size. This reduction (concentration) is accomplished by panning the sample, in a standard 16-inch gold pan, down to a black sand concentrate or by processing in mechanical washers, sluices, or jigs. Hand panning is required in the mechanized processes as a final step. Therefore, the mineral examiner should sharpen his panning skills by practicing panning in a tub using lead shot as the recoverable mineral.

Special care must be taken in the concentrating procedure to ensure retention of all gold values. In many placer deposits, the bulk of the gold values are composed of finely divided particles such as flour gold, which are extremely difficult to capture. Fine gold values can run between 10 percent and 100 percent of the total recoverable values of the deposit.

The detailed sampling of detrital placer deposits is given in Wells (1968) and in MacDonald (1983). These publications should be consulted prior to sampling any detrital placer deposit.

In addition to the field checklist in chapter III-4, the following points should be recorded in your notes for the sampling of detrital placer deposits:

A. Physiography and climate - working season.

B. Size of deposit (total yards, yards recovered).

C. Gradient of deposit (percent) or (ft./100 ft.).

D. Has the area been worked before? - describe sample sites, sample results, production history.

E. Overburden; type, extent, compaction; depth and depth to ground water surface.

F. Bedrock - type, relief on, depth to, smooth, jagged, jointed, slatey, pot-holed, solution cavities.

G. Describe the nature of deposit - massive, stratified, channeled, thickness (average, range), induration, cementing agents, caliche layers, roots, and clay.

H. Describe the composition and texture - composition of clasts, roundness and sphericity of clasts, sorting (grading), ratio of -1/4 inch to (+ 1/4 inch to 10 inches), sized clasts, amount, and distribution of boulders (10 inches +), clay (amount and type).

I. Mining equipment and methods.

J. How does the miner describe gold distribution? Does he/she claim gold "locked" in black sands? What is the size, shape, and surface appearance of the gold?

K. Dimensions of sample site. Was sample taken into bedrock(?), if so, how far.

L. Weight of material (lbs/yd.^{3} - usually 3,000 lbs.).

M. Weight of sample.

N. Volume of sample. If not in-place volume, give percent swell in sample.

O. Weight of concentrate.

P. Make allowance for moisture in weight determination.

Q. Photograph sample site before and after sampling; mark sample site and number prior to taking photographs.

Representative samples are hard to obtain and therefore the results of sample analyses must be carefully considered. Four major problem areas may exist:

A. Boulders will have to be considered; certainly if they are to be mined. Boulders may be mined around, moved, or blasted.

(1) If boulders are larger than the sample cut, estimate percent of boulders for weight and add to sample weight. It is extremely important in this case to have photographs before and after sampling.

(2) If the sample is a bulk type, then boulders are weighed with the sample.

(3) If a suction dredge is to be used, then boulders may not have to be considered, as the nature of the sample is different.

B. The amount of gold in a placer deposit is very small compared to the waste material. Any error in sampling or in processing the sample will be compounded when evaluating the deposit. Errors can occur because gold has a high unit value and even a small nugget in the sample profoundly affects the calculated values. A deposit having a gold/material ratio of one to a billion by volume is worth about $0.186 yd.^{3} with gold at $420/oz.

C. Other valuable or potentially valuable minerals such as rutile, monazite, cassiterite, ilmenite, cinnabar, and so forth, generally do not present as much of a problem as placer gold because:

(1) These minerals have lower unit values so errors will not be as greatly compounded as for gold.

(2) These minerals occur in greater amounts than does gold; samples may be split safely.

(3) They often occur in finer and more uniform sized grains than gold; they are easier to sample.

The detailed sampling of detrital placer deposits is given in Wells (1968) and in MacDonald (1983). These publications should be consulted prior to sampling any detrital placer deposit.

In addition to the field checklist in chapter III-4, the following points should be recorded in your notes for the sampling of detrital placer deposits:

A. Physiography and climate - working season.

B. Size of deposit (total yards, yards recovered).

C. Gradient of deposit (percent) or (ft./100 ft.).

D. Has the area been worked before? - describe sample sites, sample results, production history.

E. Overburden; type, extent, compaction; depth and depth to ground water surface.

F. Bedrock - type, relief on, depth to, smooth, jagged, jointed, slatey, pot-holed, solution cavities.

G. Describe the nature of deposit - massive, stratified, channeled, thickness (average, range), induration, cementing agents, caliche layers, roots, and clay.

H. Describe the composition and texture - composition of clasts, roundness and sphericity of clasts, sorting (grading), ratio of -1/4 inch to (+ 1/4 inch to 10 inches), sized clasts, amount, and distribution of boulders (10 inches +), clay (amount and type).

I. Mining equipment and methods.

J. How does the miner describe gold distribution? Does he/she claim gold "locked" in black sands? What is the size, shape, and surface appearance of the gold?

K. Dimensions of sample site. Was sample taken into bedrock(?), if so, how far.

L. Weight of material (lbs/yd.^{3} - usually 3,000 lbs.).

M. Weight of sample.

N. Volume of sample. If not in-place volume, give percent swell in sample.

O. Weight of concentrate.

P. Make allowance for moisture in weight determination.

Q. Photograph sample site before and after sampling; mark sample site and number prior to taking photographs.

Representative samples are hard to obtain and therefore the results of sample analyses must be carefully considered. Four major problem areas may exist:

A. Boulders will have to be considered; certainly if they are to be mined. Boulders may be mined around, moved, or blasted.

(1) If boulders are larger than the sample cut, estimate percent of boulders for weight and add to sample weight. It is extremely important in this case to have photographs before and after sampling.

(2) If the sample is a bulk type, then boulders are weighed with the sample.

(3) If a suction dredge is to be used, then boulders may not have to be considered, as the nature of the sample is different.

B. The amount of gold in a placer deposit is very small compared to the waste material. Any error in sampling or in processing the sample will be compounded when evaluating the deposit. Errors can occur because gold has a high unit value and even a small nugget in the sample profoundly affects the calculated values. A deposit having a gold/material ratio of one to a billion by volume is worth about \$0.186 $yd.^3$ with gold at \$420/oz.

C. Other valuable or potentially valuable minerals such as rutile, monazite, cassiterite, ilmenite, cinnabar, and so forth, generally do not present as much of a problem as placer gold because:

(1) These minerals have lower unit values so errors will not be as greatly compounded as for gold.

(2) These minerals occur in greater amounts than does gold; samples may be split safely.

(3) They often occur in finer and more uniform sized grains than gold; they are easier to sample.

D. Sometimes unusual materials occur in a deposit and must be identified and evaluated.

To prevent salting, either accidently or on purpose, the following precautions should be followed:

A. Examine and clean all equipment used in sampling and sample processing before, during, and after use.

B. Guard samples.

C. Clean sample sites before taking samples.

D. Placer gold requires special attention to the following:

(1) Check for shavings (indicates fraudulant salting).

(2) Record color: bright yellow, silverish, coated with Fe, or Mn stained.

(3) Surface texture: rough, smooth, pitted.

(4) Any rock particles adhered to the gold.

(5) Shape: round, angular, flaky.

(6) Size.

a. Coarse: +10 mesh, large sizes called nuggets.

b. Medium: -10 mesh to +20 mesh, about 2,200 gold particles per oz.

c. Fine: -20 mesh to +40 mesh, about 40,000 gold particles per oz.

d. Very fine: -40 mesh, about 40,000 gold particles per oz.

E. Examine the black sand after separation by panning or mechanical means and record the following data:

(1) Is the gold stuck to the sand grains? Is abrasion required to remove the gold from the sand grains?

(2) Is the gold coated with Fe or Mn? Is scouring required to clean the gold particles?

(3) Is gold "locked" in the black sand grains? Does the miner claim the "locked" in gold?

4. Sampling of Dumps.

There are two types of dumps which may be encountered, tailings and waste dumps. Tailings dumps are discharged from the mill and are finely ground and crushed material generally less than 2 inches in size. Waste dumps are broken rock excavated from the mine in the course of exploration, development, and production. The material on a waste dump may range in size from minus 1/4 inch to boulder size. Rock considered as waste in the past may be considered as ore today, due to changes in technology and economics.

The following preliminary work is performed prior to sampling a tailings or waste dump:

A. A topographic map of the dump is prepared so that its length, width, and thickness can be accurately determined to measure the volume of the dump.

B. The thickness of the dump can be obtained by one of two methods. The first is to drill a number of holes through the dump to the surface upon which the dump material rests. The second method is to map the bottom of the dump, if sufficient exposures are available to project the underlying ground topography. It may be necessary to subdivide the dump into smaller blocks in order to properly measure the volume of the dump, especially if it lies upon an irregular surface.

C. A sampling grid of the dump is laid out in the following manner:

(1) A base line is laid out along the long axis of the dump, using stakes, ropes, or flagging tape. At least five evenly spaced sampling points are established: one at the dump's center, and the rest evenly spaced towards the ends of the dump, with one each halfway between the center of the dump and the dump's end, and one each at 90 percent of the distance from the dump's center and end of the dump.

(2) Five cross lines are established at right angles to the base line, one through its center point, one each at the halfway point between the center and the dump's ends, and one each at 90 percent of the distance from the dump's center towards the end of the dump.

(3) At least five evenly spaced sampling points are established on each cross line, the central one of which is on the baseline.

D. Before sampling, the tonnage of the dump should be determined. The tonnage is obtained in the following manner:

(1) From at least three, and no more than five, widely spaced sites on the dump, remove a measured in-place cubic foot of material from the dump.

(2) Weigh each sample.

(3) Average together the individual sample weights to obtain an average weight per cubic foot for the dump.

(4) From the topographic survey of the dump, calculate the number of cubic yards of material contained in the dump.

(5) Multiply the number of cubic yards by 27. Multiply that product by the average weight per cubic foot obtained from (3) above. Then convert to short tons of material by dividing by 2000 pounds.

After performing the above calculations, the sampling may begin. Depending upon the size of the material in the dump, several methods may be used as follows:

A. Tailings

(1) One method is to drive a 2- to 4-inch diameter pipe into the dump at each sample point. The pipe is removed, along with its contents, and the contained sample is bagged for assaying. The depth of sample can be varied by using different lengths of pipe or by redriving the same pipe over again in the same hole.

(2) A second method is to drill the dump, either by auger, churn drill, or with reverse circulation equipment.

(3) Pits or trenches can be excavated, although these should be done with caution because of the danger of cave-ins.

B. Waste dumps

(1) These are difficult to accurately sample since the size of the dump material varies considerably. Caution should be exercised in sampling waste dumps for safety reasons and to avoid unnecessary sampling errors.

(2) Assuming that the dump is of uniform consistency throughout (which is not always the case), a series of pits may be dug at each sample point. A certain number of shovelfuls of material from each pit is collected for the assay sample. As an example, each 4th, 7th, and 10th shovelful (each shovelful to be of equal volume) is dumped into the sample bag and mixed together to form the assay sample.

(3) If the dump is zoned, containing several "blankets" of differing material, trenching in partway from the outside edges, followed by digging one or more small pits or shafts along the baseline may be necessary either by hand or with a backhoe. The pits and trenches are sampled in the usual manner.

(4) Drilling of the dump by using augers, churn drills, or reverse circulation equipment may offer the best results, if technically feasible.

The grade of the dump is calculated by blocking the dump out into areas of influence for each sample point, averaging the areas into assay blocks, and then averaging the blocks together to obtain the average grade of the dump. (See Popoff (1966)). The weighted average method is used to obtain the most accurate estimate of the grade. If the baseline and cross lines were properly established, the average grade can be calculated by the use of the Prismoidal Formula. (See Chapter V-4C). If the dump is highly irregular in outline, other geometric formulas may be used to calculate the volume and to average the grade of the dump. (See Popoff (1966)).

5. <u>Assaying</u>.

The analysis of samples is very important and requires considerable care by the mineral examiner. Be sure that the analytical laboratory has a good reputation and is qualified to perform the required assays. Erroneous or unreliable assays can lose the Government's case in an administrative hearing. The lowest bid is not always the best route to follow in selecting a competent assayer.

The amount of placer gold should be determined by the free gold amalgamation method. Any other process gives an inaccurate value which will be higher than the actual value of gold recoverable by placer mining. The tailings from placer operations should be fire assayed to check for gold lost in the operation, and an emission spectrographic analysis done on the black sands recovered to check for rare earths, titanium, columbium, tantalum, and the platinum group minerals. If these are found in significant amounts, have the black sands assayed.

Gold and silver from lode or vein deposits should be fire assayed. The detection of high levels of gold is erratic with atomic absorption (AA) spectrophotometry. This method will work for silver, detecting silver at levels as low as 2-5 ppm (0.0583-0.146 oz/ton).

The AA method for most other elements is standard procedure in the analytical industry. Molybdenum and tungsten at levels of less than 50 ppm, must be analyzed colorimetrically. Uranium is best analyzed by either fluorimetry or neutron activation. The platinum group metals also require special analytical methods that are not available at many laboratories.

The micron sized disseminated gold deposits (Carlin type and other low grade, large tonnage gold deposits) which will be heap or vat leached, require a special test for gold recovery. This is the column percolation or bottle agitation cyanide leach test, where the sample is leached with cyanide, passed through a charcoal column, and recovered by several methods. A 60-pound sample is required. The Bureau of Mines at Reno has a test plant available for this purpose.

If you have a special analytical problem and are unsure about the proper analytical technique required to produce a reliable assay value, consult Rose, Hawkes, and Webb (1979) or Levinson (1974). Checking with your local lab is also advisable. The Bureau of Mines and the Geological Survey will perform analytical work on a time-available basis, but that work should be requested only for special needs.

CHAPTER V. Evaluating a Mineral Deposit

1. General Requirements and Process.

The purpose for evaluating a mineral deposit is to determine the probable cost of mining or extracting mineral values, weighing those costs against the probable returns gained by selling the product, and determining if the operator has a reasonable prospect of success in developing a valuable mine.

To obtain an estimate of an ore deposit's probable profitability, a number of factors must be considered. Among these are the following:

A. The grade, tonnage, and gross value of the ore.

B. Capital costs, both debt financing and equity financing.

C. All costs incidental to operating the mine, processing the ore, and reclamation of the site.

D. Marketing costs.

E. Federal and State taxation including income taxes, depletion allowance, property taxes, severance taxes, etc.

2. Classification of Reserves.

Reserves are the amount of minerals available for extraction. RESERVES IS AN ECONOMIC TERM and is the amount of valuable mineral that is economically exploitable from a mineral deposit and should not be confused with the term "resource."

A. Proven or Developed Reserves. Ore blocked out in three dimensions by actual underground mining operations or by drilling. It includes minor extensions beyond actual openings and drill holes, where the geological factors that limit the ore body are definitely known, and where the chance of failure of the ore to reach these limits is so remote as not to be a factor in the practical planning of a mine's operations. An ore deposit which has been reliably established as to its volume, tonnage, and quality by approved sampling, valuing, and testing methods supervised by a suitably qualified person.

B. Probable Reserve. Extensions near the proven ore, where the conditions are such that ore will probably be found but where the extent and limiting conditions cannot be precisely defined as for proven ore. Probable ore may also be ore that has been cut by scattered drill holes but the holes are too widely spaced to assure continuity of the ore. Ore partly exposed by development, sampling driving, or drilling but not fully blocked out. Usually such ore ranks as probable when exposed and sampled on two or three sides.

C. Possible Reserves. A reserve whose existence is a reasonable possibility, as based primarily upon the strength and continuity of geologic-mineralogic relationships and upon the extent of ore bodies already developed, and a measure of whose continuity is therefore available. Possible ore cannot be assigned a grade with any practicable certainty nor can the quantity be expressed as a definite absolute amount.

D. Reserves for Discovery and Mineral Lands.

(1) For the purpose of discovery proven and probable reserves can be used to calculate the economics of the property. See United States v. J. Gary Feezor et al., 74 IBLA 56 (1983).

(2) For a group of mining claims, once a physical exposure of a valuable mineral has been shown on each claim, the claims can be grouped together and treated as a single deposit for purposes of reserve and economic calculations (See Schlosser v. Pierce, 92 IBLA 109 (1986).

(3) For the purposes of establishing the mineral character of the land, and for extending the discovery within the limits of a mining claim, any combination of proven, probable, and possible reserves may be used.

(4) In a contest proceeding involving discovery, the probative value of proven and probable reserves is much greater than that of possible reserves.

3. Calculating the Grade and Width of a Mineral Deposit.

Several acceptable methods of calculating ore reserves are available. The most commonly used method, applicable to drill core, channel samples, and chip samples, is the weighted average method, as follows:

$$\text{AVERAGE GRADE} = \frac{\text{The summation of (width x interval x assay)}}{\text{The summation of (width x interval)}}$$

The width is the width of the sample cut or the diameter of the drill core or hole, the interval is the length of the sample cut or the length of the core, and the assay value is the content, by weight percent, of the material of value contained in the volume sampled.

The average width of the deposit is required to obtain the average volume of the deposit for the calculation of tonnage. Remember that in small vein or lode deposits, the minimum mining width of any operation is 3 feet. If the vein is 2 feet wide, an extra foot of waste will be mined and must be taken into account in the calculation of average grade and average width.

$$\text{AVERAGE WIDTH} = \frac{\text{The summation of (width x interval)}}{\text{The summation of (intervals)}}$$

The above two formulas give the average grade of the deposit in terms of its average width. The average grade and width are used to calculate the ore reserves of the deposit. This calculation is described in section V-4C. Other formulae are given in Peters (1978), Parks (1957), Popoff (1966), and McKinstry (1948) for calculations involving irregular sample spacings or variations in the density of the ore.

4. Calculating the Tonnage of a Mineral Deposit.

A. The first step in calculating the tonnage of an ore deposit is obtaining the density of the ore and rock to be mined. For a homogenous deposit, the process is easy. If the deposit has sharply contrasting densities in the ore zone, the deposit is divided into blocks of equal density and the blocks averaged to provide a density value for the deposit as a whole. This data is normally obtained from the mining claimant, but if not available, then one of the following three methods will provide an estimate of the density of the ore if the tables in Appendix IV A-D are not applicable.

B. Density Determination of Pounds Per Cubic Feet. (Modified from Peele, 1941.)

Method One. Using a 500 or 1000 cubic centimeter flask or cylinder:

(1) Fill cylinder or flask partially with water (at least half full) and read the miniscus.

(2) Obtain dry weight of sample in grams, all pieces to be less than one inch in size.

(3) Place sample into flask or cylinder.

(4) Observe and record miniscus level.

(5) Take the difference between the initial and final miniscus readings to calculate the volume of water displayed by the sample.

(6) Then:

$$\text{lbs/ft}^3 = \frac{62.5 \text{ X dry weight of sample in grams}}{\text{Difference in water volume in cubic centimenters}}$$

Method Two. By using a water filled drum with a spigot affixed two-thirds of the way up the drum from the bottom, and with the water level at the level of the spigot do the following:

(1) Weigh an empty pail.

(2) Place the empty pail under the spigot.

(3) Weigh, then place 20 to 50 pounds of average grade ore into the drum.

(4) Make sure that ALL DISPLACED WATER goes through the spigot and into the pail.

(5) Weigh the pail of water.

(6) Subtract the weight of the pail.

(7) Then:

$$\text{lbs/ft}^3 = \frac{\text{62.5 X dry weight of ore in pounds}}{\text{Weight of water displaced in pounds}}$$

Method Three. Weigh sample, first in air, then in water. Pounds per cubic foot is then:

$$\text{lbs/ft}^3 = \frac{\text{62.5 X Weight in Air}}{\text{Weight in Air - Weight in Water}}$$

C. Reserves are calculated by dividing the mineralized rock volume by a tonnage factor. The rock volume (in cubic feet) is calculated by the use of any geometric formula (or series of formulas) that best fits the shape of the deposit. The average volume of a deposit can be calculated from the Prismoidal Formula or the formulas contained in Peele (1941, Chapter 36) or Popoff (1966). By the Prismoidal Formula, the volume of any prism, pyramid, or frustrum of a pyramid may be calculated:

A_1 = Area at one end of the body
A_2 = Area at the other end of the body
A_m = Area of the middle between the two end surfaces
h = Distance between the two end surfaces.

The volume (V) of the body is then:

$$V = \frac{h}{6} (A_1 + 4A_m + A_2)$$

The tonnage factor is calculated from the formula:

$$\text{TONNAGE FACTOR (cubic feet per ton) equals: } \frac{2000}{\text{lbs. per cubic foot}}$$

The pounds per cubic foot is taken from the process above or can be taken from the density tables in Appendix IV.

5. Calculating Grade and Tonnage from Drill Holes (Modified from Peele, 1941).

A. Average Assay of One Drill Hole:

V_1 to V_n = Assays of successive samples of drill core from the hole

L_N to L_1 = Respective sample lengths down the hole of V_1 to V_n

$$V_a = \frac{V_1L_1 + V_2L_2 + *** V_nL_n}{L_1 + L_2 + *** L_n}$$

V_1 to V_n = Assay values down the hole

A_1 to A_n = Area of influence of drill hole in square feet

D_1 to D_n = Depth of drill holes in the mineral deposit

A_t = Total area of the mineral deposit in square feet

V_a = Average assay value of the mineral deposit

D_a = Average depth of the mineral deposit

T = Total tonnage of the mineral deposit

C = Cubic feet per ton in place, of the mineral deposit

n = number of drill holes

B. For Irregularly Spaced Drill Holes:

$$V_a = \frac{A_1V_1D_1 + A_2V_2D_2 + *** A_nV_nD_n}{A_1D_1 + A_2D_2 + *** A_nD_n}$$

$$T = \frac{(A_1 + A_2 + *** A_n)D_a}{C}$$

C. For Regularly Spaced Drill Holes:

$$V_a = \frac{V_1D_2 + V_2D_2 + *** V_nD_n}{nD_a}$$

$$D_a = \frac{D_1 + D_2 + *** D_n}{n}$$

$$T = \frac{A_tD_a}{C}$$

6. Calculation of the Recoverable Metal or Mineral Content of a Deposit.

A. Rock in Place.

The gross metal or mineral content of a deposit is calculated by multiplying the ore reserve tonnage by the average grade of the reserve. Mining operations are based on the RECOVERABLE ORE RESERVES which take into account the dilution of the ore grade caused by the unevenness of the deposit, and the loss of ore by leaving pillars of ore to support the back of the mine. The actual recoverable reserves in terms of metal or mineral content are calculated by the formula:

$$RMT = \frac{[RV \times (100-ML)]}{TF} \times \frac{100\%}{(100\% + DF)} \times G$$

Where:

RMT is the recoverable metal or mineral content.
RV is the rock volume in cubic feet.
TF* is the tonnage factor in cubic feet per ton; which is dependent upon the specific gravity of the ore, the porosity of the rock, and the moisture content of the rock.
DF is the percentage of dilution from the mining of the ore.
ML is the percentage lost in mining due to ore being left in pillars.
G is the average grade of the ore.

* Consult the graphs in Park (1957, page 110), or Badgley (1959), to obtain porosity and moisture corrections to rock volumes for ore reserve calculations.

The gross value of the ore per ton is obtained by multiplying either the gross metal or mineral content per ton or the recoverable metal or mineral content (RMT) per ton by the current market price for the metal or commodity. These prices are published weekly in The Northern Miner for many metals, and monthly in the Engineering and Mining Journal for almost all commodities and metals that are bought and sold in the free world marketplace.

Odd-shaped or large disseminated deposits (such as porphyry type copper and molybdenum deposits and Carlin type gold ores) may call for more sophisticated methods of calculating ore reserves. For the interested reader, these are covered in detail in Parks (1957), McKinstry (1948), Popoff (1966), Peters (1978), Reedman (1979), Lacy (1983), and VanLandingham (1983).

B. Placer Deposits.

The value of placer deposits are normally based on the value per cubic yard by using the following formulas:

Value of gold in cents per milligram = $\frac{\text{Au in \$/Tr. oz x fineness x 0.1}}{\text{31,103.5 mg/Tr. oz}}$

(Fineness is the Au content of the sample, in parts per thousand).

Example: $\frac{\$400/\text{oz} \times 850 \times 0.1}{31{,}103.5 \text{ mg/oz}} = 1.093$ ¢/mg

Value of gold in \$ per cubic yard = $\frac{\text{Recovered Au in mg} \times \text{value in ¢/mg} \times 27\ \text{ft}^3/\text{yd}^3}{\text{size of sample in ft}^3 \times 100}$

Example: $\dfrac{56.3 \text{ mg} \times 1.093¢/\text{mg} \times 27 \text{ ft}^3/\text{yd}^3}{2 \text{ ft}^3 \times 100} = \$8.307$

Milligrams of gold per cubic yard =

$$\frac{\text{Weight of 1 yd}^3 \text{ of material} \times \text{mg of Au recovered}}{\text{Weight of sample removed}}$$

If a suction dredge is used, then the gold recovered and the dollar value of the gold should be reported as milligrams per hour and dollars per hour of output.

Many placer deposits are covered by overburden to varying depths. This overburden must be removed before or during the mining operation and therefore must be considered in the overall value of each sample.

Weight Value = Gravel plus overburden

(Assume that vertical section is representative of volume at sample location.)

Example:	Overburden thickness	= 2.4'	= 0.80 yd
	Gravel thickness	= 5.2'	= 1.73 yd
	Total thickness	= 7.6'	= 2.53 yd

Overburden thickness x recovered values = .80 x \$0.0 = 0
Gravel thickness x recovered values = 1.73 x \$8.307 = \$14.37

$$\frac{\$14.37}{2.53 \text{ yd}} = \$5.68/\text{yd}^3$$

7. Calculating the Operating Costs of a Mine.

In most cases, operating cost data for a planned or existing mine are obtained from the mine operator. In some cases however, the mineral examiner may have to calculate the costs of proposed mine operations. Several excellent sources of information are available for this purpose. These are O'Hara (1980), Western Mine Engineering, Clement, Jr., et al. (1981), Hoskins (1982), and Hoskins and Green (1981). Several methods of estimating costs may be used. These are cost indexing, comparative costs in the same mining district, and grass roots estimating.

A. Cost Indexing.

This method is used if you know what the cost of equipment or services have been in a previous year and you need to know what the cost is now. The U.S. Departments of Labor and Commerce publish monthly and annual cost indices for a large range of commodities and services including mining and milling. Indices are also found in Western Mine Engineering and Hoskins (1982). An example is a D-8 Catapiller bulldozer that cost $150,000 in 1979 and you need to know its cost in 1982. Its estimated cost would be:

$$\text{1979 cost} \times \frac{\text{1982 cost Index}}{\text{1979 cost Index}}$$

$$\$150{,}000 \times \frac{343.8}{256.2} = \$150{,}000 \times 1.34 = \$201{,}000$$

B. Comparable Operations in the Same Mining District.

Many established mining districts utilize mining methods that are similar. The cost per ton of ore or cubic yard of gravel removed will usually vary by only $\pm$ 10 percent between properties. If operating cost data is available for two or three properties in the district, then operations of equivalent size, in terms of tons of ore or gravel removed per day, should be close to the average cost obtained from known operations.

C. Grass Roots Estimating.

This situation requires scoping out and estimating the project, or parts of a project from scratch. The references cited in cost indexing above, especially Western Mine Engineering, contain up to date purchase costs of equipment and services. Another source is the manufacturer of the equipment. Equipment and improvements on site already owned and paid for cannot be capitalized into the project. See United States v. Mannix, 50 IBLA 110 (1980). Under the Mannix rule, capital costs incurred prior to the date of the mineral; examination or withdrawal, cannot be amortized into the operation's cash flow.

This is because the Secretary ruled in Castle v. Womble, 19 LD 457 (1894), that it was the ..."further expenditure of labor and means..." not the past expenditures, that made a Prudent Man. This holding does not apply, however, to the calculation or apportioning of operating costs of an operation. For a small "mom and pop" operation, the standard for wages is the minimum wage; not union or contract wage scales. See United States v. Nettie G. Harper, 8 IBLA 357 (1972).

D. Milling Costs.

The costs of processing ore may be obtained from the operator or from the graphs in O'Hara (1980), Clement Jr. *et al*. (1981), Hoskins and Green (1981), and Hoskins (1982). The cost of water and disposal of tailings and waste should also be considered. Merritt (1984) is an excellent source of comparative data for benefication and mill circuits for many ores. The final cost output is in dollars per ton of rated capacity of the mill.

E. Smelter Schedules.

If the mine sells its own output through a custom smelter, instead of Free on Board at the mine site, the cost of smelting or ore reduction will have to be considered. Smelter schedules will have to be obtained from the mine or smelter operator. *Western Mine Engineering* has several smelter schedules for various commodities in the western United States and Canada. Smelter schedules have the following components:

Charges: The basic cost of smelting and handling of the ore.

Deductions: That portion of the received minerals that is not paid for, mainly for losses during smelting.

Penalties: The additional cost to the smelter for treating undesirable elements in the ore. Arsenic, for instance, carries a very stiff penalty, as does a high moisture content.

Premiums: Credits given for elements contained in the ore that are needed in the smelting process. Silica is a premium element in the smelting of copper ores.

F. Reclamation and Environmental Costs.

The cost of reclamation of a mine site and for environmental control measures at the mine and mill must be taken into account in estimating the operating costs. Reclamation costs may be found in Paone *et al*. (1974) and Johnson *et al*. (1982).

8. The Marketing of a Mine's Products.

The final step in evaluating a mining operation is determining if the product of the mine can be marketed. Minerals that are intrinsically valuable; such as gold silver, copper, lead, zinc, molybdenum, and other metallic minerals, are inherently marketable as there is an established national or world market for them. A potential market may be identified by consulting the latest published prices in the Engineering and Mining Journal or the Northern Miner. If the published price, converted to a price per ton, exceeds the cost per ton for operating and marketing costs, a market exists for the mine's products.

A. Industrial Minerals.

Minerals which are not intrinsically valuable, such as some industrial minerals, and materials with only local or regional markets, require an extra showing of marketability. See Layman v. Ellis, 52 LD 714 (1929), Secretarial Opinion, 54 LD 294 (1933), Solicitors Opinion M 36642, 69 ID 145 (1962), and United States v. Coleman et al, 390 U.S. 599 (1968). The nature of this showing is stated in Foster v. Seaton, 271 F. 2d 836 (D.C. Circuit, 1959) where the Court outlined the following requirements:

(1) Accessibility.

a. To the deposit.
b. To the market area.

(2) Bona Fides in Development.

a. Plants and equipment.
b. Present or past usage of the property.
c. Status of mine (undeveloped, developed, or on standby).

(3) Proximity to Market.

a. Transport and haulage costs.
b. Number of users or buyers in market area.
c. Number of competitors in market area.
d. Consumption by users.
e. Production by competitors.

(4) Existence of Present Demand.

a. Sales contracts or letters of intent to purchase.
b. Present use of the commodity in the market area.
c. Is consumption in the market area greater than production by competitors?
d. Is the product of this mine of a superior quality than that of the competition?

(5) Other Factors.

a. Anything not covered above that has a bearing on the (sale of the product).

B. Price or Market Fluctuations.

The Department has ruled that it is proper to consider historic price and cost fluctuations in the consideration of marketability. As stated in IN RE Pacific Coast Molybdenum Co., 90 ID 352 (1983):

> "The requirement that mining claimant show that the mineral discovered on the claim is presently marketable at a profit simply means a mining claimant must show that, as a present fact, taking into consideration historic price and cost factors as well as the likelihood of their continuance or change, there is a reasonable likelihood of success that a paying mine can be developed."

With certain commodities, especially gold, silver, and some base metals, prices can fluctuate considerably over several years. This fluctuation must to be taken into account when making projections on the viability of an operation. Current market trends and historic price fluctuations must be taken into account. In these cases, it is recommended that a 5-to 10-year average is taken in current constant dollars for the commodity's annual price on the market, as given in the Commodity Summaries of the Bureau of Mines. The average can be projected forward and estimated prices falling within ± 10 percent of the projection can be considered to be close enough in value for this purpose. Another method is to use the official projections of consumption and projections of the Bureau of Mines as given in the Commodity Summaries.

C. Unmarketable Material.

Industrial minerals, such as sand, gravel, perlite, gypsum, limestone, cinders, and building stone, are of widespread occurrence and have a low unit value. They may exist on the property in far greater abundance than can be reasonably marketed at present or in the reasonably foreseeable future. See United States v. Oneida Perlite, 88 ID 772 (1981); United States v. Claire Williamson et al., 87 ID 34 (1980); Melton E. Baker v. United States, 613 F. 2d 224, (9th Circuit, (1980)) cert. denied 49 USLW 3710 (1981); and McCall v. Andrus, 628 F. 2d 1185, (9th Circuit (1980)), cert. denied, 449 U.S. 932 (1980).

In this instance, the appropriate test is whether the reserves of each mining claim individually can enter the market. Each mining claim must stand on its own. In the case of placer mining claims, each 10-acre unit is examined in this context. The amount of reserves held by a mining claimant as well as the total available reserves in the general market area may be considered. The mining claimant's holdings must be considered in the same manner as other competitive sources of the same material. The amount of reserves reasonably marketable in this limited instance will be determined on a case-by-case basis by the mineral examiner.

9. Economic Analysis of a Mineral Property.

The fair market value of the mineral estate or property must be determined in processing a section 209(b) of FLPMA application for the purchase of the Federal mineral estate; or in appraising a mineral property for sale, exchange, or condemnation. An economic analysis may be necessary to ensure the viability of the proposed operation in cases involving the marketability of industrial minerals with large reserves and a limited market.

A. Net Value of the Ore.

The net value of the ore is calculated from the process followed in sections V-1 to V-8 of this chapter. The net value is the gross value of the ore in dollars per ton less the costs, in dollars per ton, of mining, milling, and marketing the ore. The costs are computed up to the point of delivery either FOB at the mine site, the smelter, or to a third party purchaser.

B. Calculation of Operating Cash Flow.

The calculations will vary from State to State as they must be tailored to conform to State and local tax laws. The life of an operation may be estimated by using Taylor's Rule of Thumb (Hoskins and Green, 1982, p 7) by taking the 4th root of the ore tonnage (in millions) and multiplying that number by 6.5. If a company has a different production life planned, use that projection for the calculations. A company's 10-K report, filed with and available from the Securities and Exchange Commission, is a good data source for operating cash flows.

C. Net Present Value Calculations.

To obtain the net present value of a property, its future net earnings, over its projected life span, are converted to present day value by a discount process. The Discounted Cash Flow (DCF) method establishes both the net present value of a property and the Internal Rate of Return (IRR) for the project. The IRR is the forecast of the payback to the investors in the project. For mining operations the DCF rate is considered to be the minimum return for prudent investment in the market place at the time of the examination.

To calculate a DCF, the operating cash flow must be adjusted to a net cash flow. The net operating cash flow is discounted at an appropriate rate of return and the values for each year are summed over the life of the project.

The Bureau of Land Management has a mine simulation and evaluation program called MINSIM available through the Denver Service Center. It can be accessed on the State Office level-six computers. This program will calculate the economic profile of a mining operation. The profile can be varied to give minimum necessary prices for commodities for profit, IRR, net present value, and other data useful for this line of work. It does require accurate cost and production estimate in order to accurately calculate results.

The DCF process requires an understanding of cost estimation for mining operations and a working knowledge of mineral economics and taxation requirements. A DCF analysis should not be attempted by mineral personnel until they have had training in cost estimating.

CHAPTER VI. The Mineral Report

1. General Requirements.

The mineral report conveys the examiner's professional opinions, based upon factual technical data and should conform with Bureau Manual Section 3060 unless the BLM State Office mineral examiner agrees to modifications for unusual circumstances. For matters of style consult the Suggestions to Authors of the Reports of the U.S. Geological Survey, (6th ed.), Bishop et al. (1978). The report should be concise, ensuring that all data support the conclusions.

The writer of a mineral report should always acknowledge the sources of data and information used in the report. CONFIDENTIAL INFORMATION USED IN THE MINERAL REPORT CANNOT BE RELEASED WITHOUT THE WRITTEN CONSENT OF THE OWNER OF SUCH INFORMATION. Government employees and officers who release confidential information without the written permission of the owner are in violation of 18 U.S.C. 1905, which requires that all such violators be removed from office or their job, and if prosecuted and convicted, be fined up to $1,000 or jailed for up to 1 year, or both.

A Memorandum of Understanding with other surface management agencies may allow other agencies to perform mineral examinations for the BLM; such an agreement gives the cooperating agency certain responsibilities. The other agency is essentially under contract to BLM. For the purposes of 18 U.S.C. 1905, the agency is a secondary office of control for the Department of the Interior in handling proprietary and confidential information submitted by a mining claimant whose mining claim is being investigated. The agency cannot release such proprietary or confidential material without either the written consent of the owner of such information or the permission of the appropriate BLM State Office. The final adjudicative action with a validity examination rests with the appropriate State Director of the BLM and not with the cooperating agency.

2. Review Process for Mineral Reports.

All mineral reports for validity examinations, including those prepared by other agencies or by contract, must be reviewed and approved by the BLM prior to processing of the recommended action. Mineral reports must meet the standards of the Department of the Interior in effect at the time. Reports that are not satisfactory will be returned to the originating agency or contractor for necessary revisions.

The Department of the Interior standards are contained in the Bureau of Land Management Manual Sections 3060 (Mineral Reports) and 3890 (Mineral Investigations). Review is standardized through the use of Bureau form 3060-2 (Mineral Report Evaluation). This form is the checklist to ensure that all legal and technical criteria for the proposed action are met.

CHAPTER VII. Testifying as an Expert Witness

1. Preparation for a Hearing.

A mining claim contest involves an issue of fact and can only be resolved as a result of an administrative hearing. The Department of the Interior has held that the hearing procedures of the Administrative Procedures Act, 5 U.S.C. 554-559 (1982), apply to contests involving mining claims. See U.S. v. Keith v. O'Leary, et al., 63 ID 341 (1956). The hearing is conducted in a quasi-judicial manner by an Administrative Law Judge (ALJ), and the proceedings are recorded verbatim by a court reporter. The ALJ will hear the evidence and then issue a decision on the matter. Both the Government and the contestee may submit oral and written testimony. The witnesses are subject to cross-examination during the hearing by the respective counsels.

Either party may appeal the decision of the ALJ to the Interior Board of Land Appeals (IBLA). The IBLA has the delegated authority of the Secretary of the Interior to review all appealed decisions. The IBLA will either uphold the ALJ's decision, reverse the ALJ's decision, or order additional actions to be taken by the ALJ or agency to resolve the issues involved. The IBLA decision is final and binding upon the Government. The mining claimant has the right of appeal to the Federal Courts.

An expert witness is one who is qualified to speak authoritatively by reason of special training, skill, or familiarity on the subject (Blacks Law Dictionary, 4th ed., 1968). The Federal Courts have required that a government mineral examiner shall be a specialist in the evaluation of a mining claim. See Rogers et al. v. James Watt, 776 F. 2d 1376, (9th Circuit, 1984); Charleston Products v. Andrus, 553 F. 2d 1213-1214, (9th Circuit Court, 1977); Verrue v. United States, 457 F. 2d 1204, (9th Circuit Court, 1972); and United States v. Janet Copple, et al., 81 IBLA at 132, 136 (1984).

Expert witnesses are called upon for testimony related to their field of expertise. If necessary, a corroborating witness or an outside expert may be called to give supporting testimony. A mineral examiner, who is to testify as an expert witness, must first demonstrate his competence and qualifications to the satisfaction of the ALJ. For example, a mining engineer, geological engineer, or geologist can qualify as an expert witness on mining or geology only, unless the proper foundation has been laid to qualify him as an expert on other aspects of the mineral property. Foundations can be established on the basis of the examiner's education and professional experience. The Government's counsel develops these foundations at the opening of the hearing.

Do not underestimate your status as an expert witness. You will generally be the major witness for the Government. What is said on the witness stand not only may affect the Government's case, but may also be a factor in establishing "case law" through the court decision. The mineral examiner must be well prepared when presenting testimony at a hearing.

At his/her discretion, or upon request of either party, the ALJ may order a prehearing conference. The purpose of the prehearing conference is to speed up the hearing by simplification of the issues; to exclude irrelevant issues by obtaining stipulations, admission as to uncontested facts, and agreements to the introduction of documents; to limit the number of expert witnesses; or to deal with other matters that may aid in the disposition of the proceeding.

Once the date has been scheduled for the prehearing conference or hearing by the Office of Hearings and Appeals, the mineral examiner and the counsel for the Government must review all issues and facts of the case and prepare for the hearing. It is incumbent upon the mineral examiner to acquaint the counsel for the Government with every technical question involved in the case. If more than one mineral examiner has been involved, all mineral examiners should be present for the conference. The mineral examiner and counsel for the Government will review the adequacy of all documents, maps, photographs, assay certificates, and other supporting evidence to be used at a contest hearing. Three copies of each exhibit should be prepared for the hearing; one for the ALJ, one for the opposing counsel, and one for the Government's counsel. The ALJ will provide at least 30 days advance notification of the time and place for the hearing.

The mineral examiner should maintain a working file for reference until the case is finally decided. If at all possible, revisit the mining claim(s) or mill site(s) shortly before the hearing to determine whether or not there has been recent activity. Review all calculations, grade and tonnage estimates, mining costs, and other pertinent information. If considerable time has elapsed since the field examination, you should update the examination, report, and calculations. These will be the primary topics at the hearing.

It is possible through prehearing agreements between counsels or by an order issued by an ALJ, that all or parts of the mineral examiner's mineral report may be made available to the opposing party for review prior to the hearing. When such a request is involved, the conclusions and recommendations of the report will be excluded. The mineral examiner should be prepared to define and/or explain any terms or procedures used which may be unfamiliar to the ALJ or to the opposing counsel. If the mineral report is not introduced as evidence, be prepared to testify from field notes and/or memory. Remember that anything taken to the witness stand is also subject to examination by the opposing counsel.

To effectively prepare for your testimony, familiarize yourself with the five categories of questions which the counsel will use to develop testimony:

A. TO ESTABLISH THE EXPERT WITNESS' QUALIFICATIONS. To aid your counsel in the demonstration to the court as to your competence, prepare a professional record and/or a statement of qualifications. Include education, professional licenses or registration, work experience, and publications. Counsel may introduce your record as evidence in order to eliminate the necessity for further questioning.

B. TO ASSOCIATE THE WITNESS WITH THE SUBJECT PROPERTY. The physical examination of the mining claim or mill site is covered here.

C. TO ESTABLISH THE NATURE AND SCOPE OF THE DATA CONSIDERED BY THE WITNESS. Calculations of ore reserves, analysis of the market, and mining costs, etc.

D. TO OBTAIN THE WITNESS' OPINION AS TO THE VALIDITY OF THE MINING CLAIM OR MILL SITE.

E. TO PRESENT THE REASONS FOR THE OPINION. This will be a synopsis of items covered in B and C above.

The Government, as the party initiating the contest action (contestant), presents its case first. The mineral examiner is usually called as the first expert witness. At that stage of the proceedings, the counsel for the Government develops the witness' direct testimony, thereby presenting the Government's case. Both you and the Government's counsel must be thoroughly familiar with your testimony as to the facts before the proceedings begin. At this point, you, as the expert witness, must establish the Government's PRIMA FACIE case. PRIMA FACIE is a fact presumed to be true unless disapproved by some evidence to the contrary. A PRIMA FACIE case, therefore, is one which is established by sufficient evidence and can be overturned only by rebutting evidence adduced on the other side.

During cross-examination the opposing counsel may seek to discredit both you as an expert witness and your testimony. You are largely on your own and your professional reputation is "on the line." In redirect examination your counsel will have the opportunity to review points raised in cross-examination. However, the lapse of time may result in loss of continuity, concentration, meaning, and emphasis.

During the testimony of the contestee's witness, listen attentively and write down questions that should be asked by the Government's counsel during cross-examination. You should also assist counsel in the preparation of any rebuttal evidence.

2. Hearing and Courtroom Demeanor.

Remember, that in giving expert testimony in an administrative hearing or in court, maintain a friendly, unbiased attitude. You should try to make the ALJ understand that you are there, not as a witness for one side or the other, but to give your expert opinion on the validity of the mining claim or mill site so that an impartial decision may be made. Your counsel is experienced in courtroom procedures and will do everything possible to help you be an effective witness.

When you are called to the stand as an expert witness, you must convince the Administrative Law Judge, Federal judge, and/or jury that you are qualified to give testimony. Then you must present the facts so as to leave no question of how and why you formulated your opinion. The following time-proven suggestions will help a prospective witness enhance the possibility of obtaining a decision favorable to the opinion of the expert witness.

A. SPEAK CLEARLY. Do not mumble. Speak loudly and clearly so that everyone in the hearing room can hear you. The person taking the verbatim record of your testimony must be able to hear you and record what you actually say. Do not hesitate to spell out a difficult technical term.

B. THE DECISION OF THE ALJ WILL BE BASED SOLELY ON THE TRANSCRIPT. Always make sure that you give a complete statement using complete sentences. A half statement or incomplete sentence may convey your thought at the hearing, but may be unintelligible when read later by the ALJ. Prepare a list of technical terms that will be used in your testimony and give them to the court recorder so that mispellings and word errors are avoided.

C. WHEN REFERRING TO AN EXHIBIT, always identify your reference explicitly (e.g., referring to sample point 2 on Government Exhibit A). Also, references such as "this section of the drawing" will not be clear in the written record. Be explicit.

D. LISTEN CAREFULLY TO THE QUESTION. Answer directly and simply, then stop.

E. BE POSITIVE AND GIVE DEFINITE ANSWERS WHENEVER POSSIBLE. Avoid phrases such as "I think," or "I believe," or "As best I can remember." This weakens your testimony.

F. IF YOU DO NOT KNOW THE ANSWER, SAY SO. Do not guess or make up an answer.

G. DO NOT ATTEMPT TO ANSWER QUESTIONS YOU DO NOT UNDERSTAND. Ask the examining counsel for clarification, particularly where the question is long and involved.

H. IF YOU MAKE A MISTAKE, CORRECT IT IMMEDIATELY. If your answer was not clear, clarify it immediately.

I. NEVER VOLUNTEER INFORMATION. Answer the question that was asked, not what you think was intended. The transcript will show only the question asked, not what was in the mineral examiner's mind. Remember, no matter how nice the opposing counsel may seem on cross-examination, his job is to discredit you as a Government witness.

J. DO NOT ANSWER THE QUESTIONS OF THE MINING CLAIMANT'S COUNSEL TOO QUICKLY. Never anticipate the question to be answered. Wait until it is completed before answering.

K. BE FIRM IN STICKING TO THE ANSWERS YOU HAVE ALREADY GIVEN, IF TRUE. If it turns out you were mistaken in some of your testimony, admit it. The truth is more important than stubborn consistency.

L. BEWARE OF HYPOTHETICAL QUESTIONS. Do not allow yourself to be led into expressing a positive opinion about things of which you are uncertain.

M. IF YOU ANSWER A QUESTION ON CROSS-EXAMINATION BY A "YES" OR "NO" AND FEEL THAT YOU MUST QUALIFY OR EXPLAIN YOUR ANSWER, IMMEDIATELY BEGIN THE EXPLANATION. If the mining claimant's counsel attempts to stop you by saying that you have answered his question, explain to the ALJ the need to enlarge on your answer. If you are not allowed to do so, do not worry. Your counsel will question you later on your answer.

N. CONSIDER YOUR ANSWER CAREFULLY BEFORE REPLYING to a question from opposing counsel concerning your earlier testimony. You may have your previous testimony read from the record if necessary.

O. AVOID HEARSAY TESTIMONY IF POSSIBLE. Remember, as an expert witness you are testifying to the facts upon which you based your opinion. Generally speaking, at some time during the hearing, you will be permitted to relate all the information (whether hearsay or not) upon which you based your opinion.

P. DO NOT ARGUE OR TRY TO BE CLEVER with the mining claimant's counsel. Remember, the advantage lies with the mining claimants' counsel.

Q. REFER TO OTHER WITNESSES RESPECTFULLY and in a friendly and considerate manner. Strive to convince the ALJ that you know what you are doing, that you are fair and sincere, and that you are not infallible.

R. AVOID OVERLY TECHNICAL TERMS if at all possible. If you must use them, be prepared to spell and define them for the court reporter. Refer to the list submitted to the Recorder under "B" above.

S. CONTROL YOUR EMOTIONS. Derogatory remarks or reflections on your work and ability may be made by opposing counsel. Displays of anger, confusion, or an erroneous response will give the opposing counsel a distinct advantage. If anyone is to get irritated, bored, impatient, angered, or disgusted, let it be someone else in the courtroom.

T. ABOVE ALL, BE PREPARED. There is really no reason to be frightened or nervous, if you are well prepared and know the facts relating to your testimony. Relax, and remember that you are simply telling what happened.

CHAPTER VIII. References

The references marked with an (*) are considered essential references for mineral examinations. It is recommended that they be acquired and placed in the District/Area office library of those offices that have an active mining law program.

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